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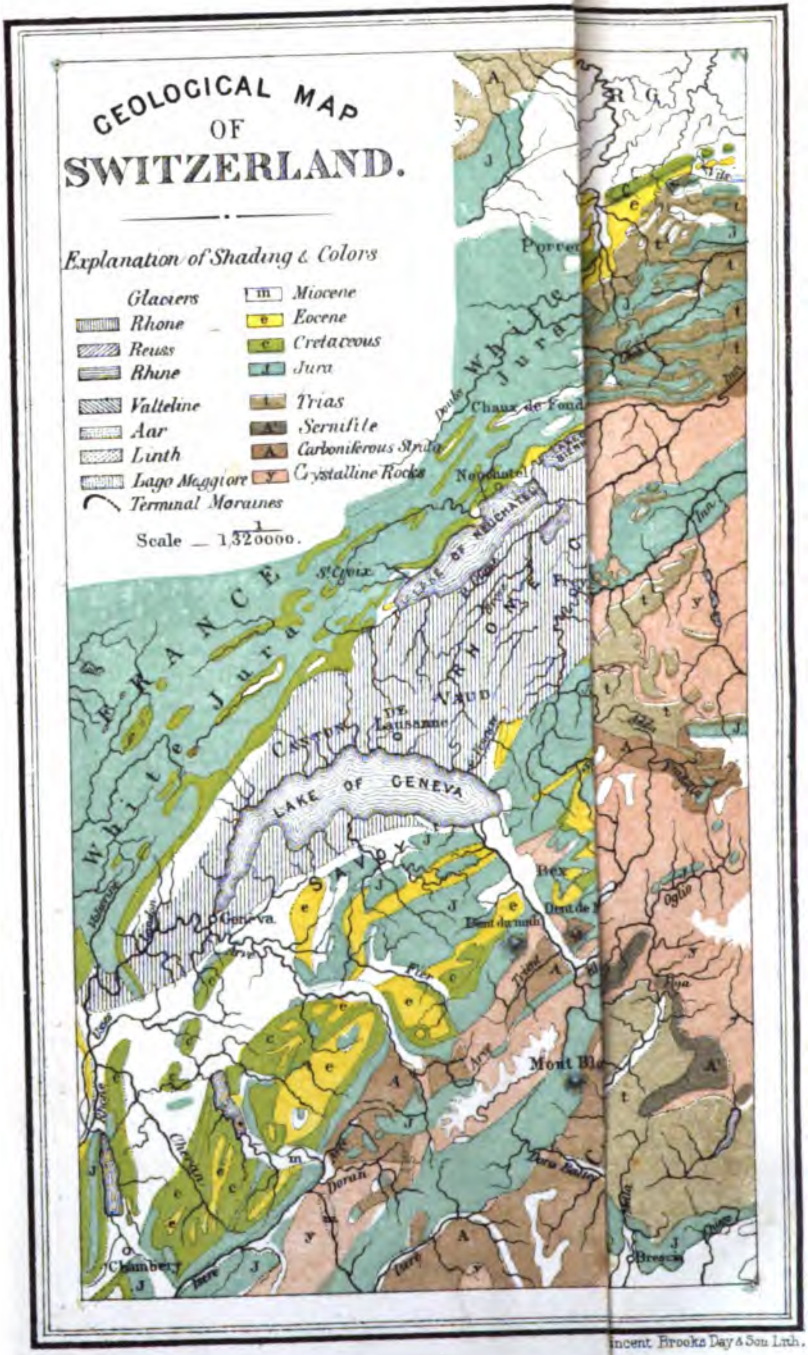

GEOLOGICAL MAP OF SWITZERLAND.

incent Brooks Day & Son Lith.

THE

PRIMÆVAL WORLD

OF

SWITZERLAND.

WITH

560 ILLUSTRATIONS.

BY

PROFESSOR HEER,

OF THE UNIVERSITY OF ZURICH.

EDITED BY

JAMES HEYWOOD, M.A., F.R.S.,

PRESIDENT OF THE STATISTICAL SOCIETY.

VOLUME I.

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ALERE FLAMMAM.

EDITOR'S PREFACE.

PROFESSOR HEER published the German edition of his 'Primæval World of Switzerland' at Zurich in 1865. His high reputation as a naturalist and geologist was recognized in England by grants from the Geological Society in 1862 and 1873, as well as by the award of the Society's gold medal in 1874.

The French translation of Professor Heer's work by M. Demole appeared at Basle and Geneva in 1872. Both the German and the French editions were placed by the English Editor in the hands of Mr. W. S. Dallas*, F.L.S., for translation; and thanks are especially due to that gentleman for the care he has bestowed on natural-history details.

In the revision of the MS. sheets for the press the French edition has been principally consulted by the Editor. Various suggestions have been kindly given to him by Professor Heer during the progress of the English work; and an arrangement has been made with the Zurich publisher, M. F. Schultess, for the same illustrations to appear in these volumes which had adorned the continental editions.

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* Assistant Secretary of the Geological Society, editor of the Society's Journal, and author of the 'Natural History of the Animal Kingdom.'

Assistance has been derived by the Editor from the 'Thesaurus of English Words and Phrases' by the late Dr. Roget, F.R.S., which comprises an admirable alphabetical index to facilitate reference. The 'Descriptive and Analytical Botany' of MM. Le Maout and Decaisne, translated from the French by the late Mrs. Hooker, has been frequently consulted, as a compendium, with beautiful illustrations, of the vegetable kingdom. The Editor has also derived aid from the Readers in the establishment of Messrs. Taylor and Francis, in the preparation of the Index as well as in the careful revision of the proof-sheets.

Various important works have been already published by Professor Heer, among which may be mentioned his 'Fossil Flora of the Arctic Regions,' in three quarto volumes, his 'Swiss Tertiary Flora,' and his Treatise on the Plants of the Swiss Lake-dwellings. An English abstract of the pile-dwellings' flora is given in Dr. Keller's 'Lake Dwellings,' translated by J. E. Lee, F.S.A., F.G.S. Professor Heer visited Madeira in 1851; and in the present work he repeatedly refers to the natural history of that island to illustrate animal and vegetable life in the Lias period* and during the Miocene† formation. The learned Professor is of opinion that the climate of Switzerland ‡ at the Miocene period was similar to that of Madeira at the present day.

---

* See *infrà*, vol. i. p. 68.

† Vol. i. p. 348, and vol. ii. p. 22.

‡ Vol. ii. p. 135.

In the Geological Museum of the Polytechnicum at Zurich, Prof. Holzhalb has an oil-painting of Swiss Miocene life, to which the Editor is indebted for the Plate at p. 62 in vol. ii. of the present work. A walnut-tree * rises to the right of the landscape, and under its branches are two long-armed apes †; in the foreground a salamander ‡ crawls on the rock, some tortoises are on the shore, and wild ducks are swimming on the Miocene sea.

Gradual development in long intervals of time has been illustrated by a series of fossil chestnut-leaves belonging to Central Europe, which were sent, in 1876, to the London Scientific Loan Collection by Baron von Ettingshausen, Professor of Botany at Grätz in Styria, and are thus described § :—

"In ancient Tertiary strata the chestnut (*Castanea atava*) had leaves distantly toothed, but devoid of any points; and from the primary vein of the leaf curved secondary veins sprang at a distance from each other.

"In the Middle Tertiary strata the secondary veins of the chestnut-leaf approximated to one another, and teeth protruded and were more numerous.

---

* *Jugulans acuminata* (see *infrà*, vol. i. p. 362).

† *Hylobates antiquus* (vol. ii. p. 81).

‡ *Andrias Scheuchzeri* (vol. ii. p. 62).

§ Catalogue of the Scientific Loan Collection. Second edition, p. 723. London, 1876.

"In the latest Tertiary strata the secondary veins of the chestnut-leaf were still nearer to each other and almost rectilinear, while the teeth of the leaf had become set with thorns, as in the sweet chestnut (*Cästanea vesca*) of our own time."

The Editor of the present work has added, in the Appendix to vol. ii., a short paper from the German Archives of Anthropology, published at Brunswick in 1875, on the traces of Man in the Interglacial formation of Wetzikon, in the Canton of Zurich; and a copy of the woodcuts which appeared in that periodical has been given, representing specimens of rude basketwork in the form of pointed rods formerly tied with some sort of band. These fragments of a basket are the most ancient relics of human workmanship found in Switzerland.

Much interest belongs to the geological statistics prepared or collected by Prof. Heer in each successive chapter of these volumes. There is also, at times, a wonderful animation in his descriptions of groups of insects which have become fossilized in the midst of their amusements.

Inhabitants of the Southern United States of North America will be gratified to recognize in Swiss Miocene strata the remains of many plants indigenous in their own Transatlantic sunny regions—

In southern lands inquiring Science finds
Fresh fruits and foliage of primæval kinds.

AUTHOR'S PREFACE.

It is well known that individual plants and animals come into life and die, but species of plants and animals have remained the same during the recorded history of the human race.

If fossil remains are examined, it is found that in the course of ages vegetable and animal species have appeared and have passed away, and that between the appearance and extinction of species vast intervals of time have elapsed.

A perpetual progress of development characterizes the surface of the earth, which is subject to continuous change.

Results of transforming agency may be noticed from the lofty summits of Swiss mountains, where the slopes are seen to be covered with fallen rocks, and cascades are formed by the rushing of torrents down steep ravines, thus wearing away masses of land.

Only a small portion of geological changes can be observed by a single human being within the brief span of life; but the mind of Man can go back for thousands of years beyond the present scene. Thought can penetrate into the past and can speculate with regard to the future, in this manner demonstrating an immortal nature.

Numerous questions present themselves with reference to Switzerland, which are intimately associated with the present modes of life and with the inmost thoughts of human beings.

What was the origin of the Swiss mountains and valleys, which possess such especial charms? How were the infinitely varied forms of plants produced, so richly embellished and so attractive? What has occasioned such a development in the forms of animals? Was it chemical action which brought into being these plants and animals? or has there been manifested, in the calling into existence of all these organisms, a determinate object, as well as a higher plan, in which is revealed the mind of a Deity fully endowed with wisdom and power?

Did living organisms first appear where now we meet with them, or did they belong to a central locality, whence they have spread over the earth? and has their present area of distribution resulted from a development carried into effect during thousands of ages? Is there a relationship between living organisms and the ancient organic beings of former periods? and are there general and eternal laws and a harmonious whole in the grouping together of all vegetable and animal organisms?

A solution of such questions has been sought for, in our day, by interrogating Mother Earth herself, who, alone, on several of these points, can furnish the requisite data for an answer.

Switzerland fortunately contains very important natural documents respecting the history of the earth; but the language must be learnt in which the documents have been written, and some effort is needed to master the primæval history of this little country.

In the present work the foundations of the edifice of science are shown in their exact position: the student has here the opportunity to study the succession of plants and animals in the different geological formations, and thus to obtain information relating to natural-history questions.

The primæval world of Switzerland comprises an account of organisms the remains of which are preserved in Swiss strata of different epochs; but the geological history of the country cannot be understood without taking cognizance of the general development of nature; so that in narrating Swiss annals of natural history we should also examine into the appearance and characteristic changes of other parts of the globe.

Having established a solid basis of scientific reasoning, we may enter on general questions leading to the final truth, thus expressed in the words of the great poet, Schiller:—

"While man's will wavers,
And in eternal movement all things circle round,
One tranquil Spirit remains firm in the midst of
the movement—
The loftiest living Mind
Soaring high over time and space,
One God, one holy living Will." *

---

* "Und ein Gott ist, ein heiliger Wille lebt;
Wie auch der menschliche wanke,
Hoch über der Zeit und dem Raume schwebt
Lebendig der höchste Gedanke,
Und ob alles in ewigem Wechsel kreist,
Es beharret im Wechsel ein ruhiger Geist!"

SCHILLER, *Die Worte des Glaubens.*

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THE
PRIMÆVAL WORLD
OF
SWITZERLAND.

CHAPTER I.

ON THE SWISS CARBONIFEROUS FORMATION.

In the world of mountains of Switzerland, the geological history of the earth is mirrored.

Mighty revolutions which have passed over the globe are portrayed in the lofty walls of rock, the deep valleys, and the wonderfully contorted strata of this interesting land; we see nature in wild disorder, mountains rent asunder, and rocks shattered.

In the same country, fertile periods of quiet development may be traced, when the tranquil surface of the earth was clothed with a rich vegetation, and land and water gave support to varied races of plants and animals, whose remains are found at the present day in rocky tombs.

The Alps no longer merely charm the mind by their silent sublimity, but Switzerland also forms a magnificent temple of Nature, into which we shall endeavour to enter, that we may investigate the wonders which adorn it, and may there follow in succession the past periods of the world's history.

The lowest and oldest story of the Swiss temple of Nature is in the Valais; and in front of that canton stand two fine pyramidal mountains, the Dent de Morcles, and the Dent du Midi.

Everywhere, as we go from the upper or eastern part of the Lake of Geneva, towards the Valais, these two mountains meet us; and between them is the main valley of the canton. The rocks at the foot of these mountains comprise remains belonging to the early Carboniferous period.

Carboniferous strata occur near the hamlet of Erbignon, as well as at Outre-Rhône on the south side of the Dent de Morcles.

Remains of numerous plants belonging to the Carboniferous period are here found in sandstone. The substance of the plants has disappeared, and is replaced by a thin coat of yellowish-white talc, of silvery lustre, which preserves the vegetable form and internal structure.

The plants look as if they had been painted with silver on a dark background.

A fine-grained shale forms the rock on the opposite or left bank of the Rhone; and from the smooth dark surface of this shale the silvery leaves of the carboniferous plants stand out beautifully. Similar shales containing impressions of leaves occur at Vernayaz in the neighbourhood of the beautiful cascade of the Pissevache, higher up on the Col de Balme, in the Valorcine, and further south, to the north-west of the village of Tour at the Posettes.

If we follow the basin of the Arve, we meet with several deposits rich in similar plants—for instance, at the Mont-du-Fer on the western slope of the Brevent, near Servoz on the left bank of the Dioza, near Moide on the right bank of the same rivulet, and further on, near Taninge in the valley of the Giffre, which falls into the Arve in the neighbourhood of Thiez. We also find anthracite shales with the same flora in the basin of the Isère—for example, near Colombe en Épulan, in the bottom of the valley of Haute-Luce, on the southern slope of Jolimont, near Lamure, and at Petit Cœur, near Moutiers.

A broad band of carboniferous rock may then be traced from the lower Valais, continued in a south-westerly direction through Savoy into Dauphiné. Carboniferous rocks may also be followed far towards the east. The mass of mountains which extends to the left, on the southern side of the valley of the Rhone, belongs in great part to the Carboniferous formation. Hitherto only a few impressions of plants have been found at the excavation of Établon—although in other places beds of anthracite occur, as at Tennen near Turtmann (Tourtemagne), at

Rechy, Grone, Bramois (near Sion), Chandoline, Baar (between Aproz and Nendaz), Aproz, Haute-Nendaz, Isérable, Laos (Entremont), Mont de Planard (Entremont-Ferret), the excavations of Chautagne and Commère (Liddes), and the Col de Fenêtre. Anthracite is altered coal, which may be employed as fuel. It has, however, been worked, as yet, only at four of the abovementioned places—namely, at Grone, Chandoline, Aproz, and Bramois*.

In the rest of Switzerland traces of the Carboniferous formation are to be found only in a few places, as on the Titlis in the Engelberg, and high up on the northern slope of the Tödi.

In the direction of the Alps we must go to the Tyrol, and to the Stangalp in Styria, to find anthracite shales similar to those in the Valais and possessing the same peculiar flora. Hence the carboniferous region of Switzerland forms an island, which occupies the western and southern parts of the Valais, and extends from that canton as far as Dauphiné. Some small islands belonging to the same formation are seen on the west of the Engelberg and of the Canton of Glarus. Whether there may be carboniferous rocks in other parts of the country cannot at present be ascertained. In the northern part of Switzerland and in the level district, if there be coal, it must lie at a very great depth; so that even in the most favourable spots, as from Rheinfeld to Basle, we could only expect to meet with coal-measures at a depth of about 1800 feet, if, indeed, such strata exist there at all.

It is certain that the whole region of the Swiss anthracite rose above the level of the sea; for in the strata of that district we only meet with the remains of land-plants, and there is an entire absence of marine animals. The deposit must have been formed in fresh water, like the Westphalian coals, in which many freshwater animals (*Unio*, *Anodonta*, and *Planorbis*) have been discovered. At the same period it is probable that the whole of the crystalline rocks, which form the axis of the central Alps, also stood above the level of the sea. Consequently, this island was of considerable size; and its existence tells us that, even at this early period of the earth's history, the Alps, which now separate Southern from Central Europe, already existed, although, doubtless, only in the form of low marshy land. In the anthracite region, the island was covered with plants; and their remains, enclosed in the rocks, furnish important evidence that the plants of this island belonged to the remarkable flora which was distributed over the earth in the Carboniferous period.

---

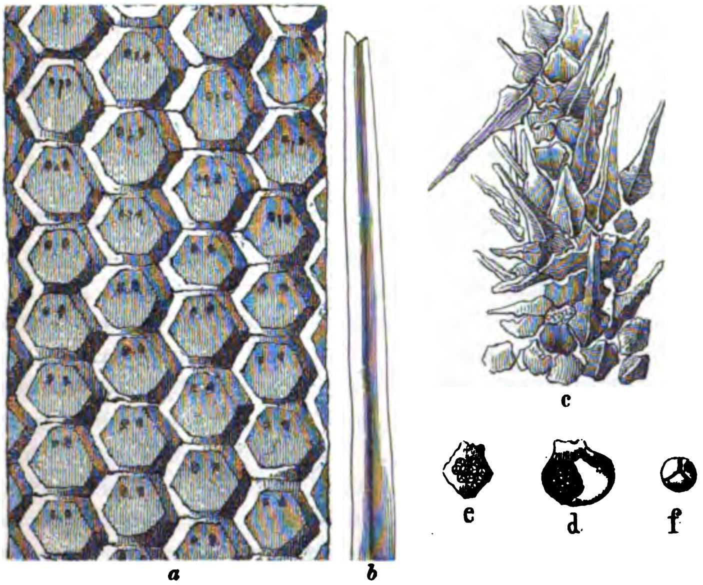
* The workings at Bramois have been abandoned for some years. The three other localities furnish annually about 60,000 cwts. of anthracite.

From these anthracitic rocks of the Valais and the district of the Arve, Professor Heer has received 46 species of plants, 36 of which are known in the coals of other parts of Europe, and 24 are found in the coal of North America. Seven species are peculiar to Switzerland; and three have been found only in the anthracite region of the Tarentaise. If we add to Swiss species those known to Swiss geologists from the district of the Isère, we get a total of 64 species, of which 51 belong to the true coal-measures, whilst 13 are peculiar to the Swiss anthracite region. Thus the majority of the species are common to the European coal-flora, and only a few rare forms are peculiar to the Swiss island; but not one occurs in any formation more recent than the coal-measures. The species are for the most part widely disseminated; and 26 of them even occur in North America. Scanty as it is, the Carboniferous flora of Switzerland comprises most of the chief types of the plants of that period, which we may now consider, in order to obtain the statistics of the vegetation of the Swiss Carboniferous island.

Of the 46 species of the Swiss flora, 28 belong to the Ferns, 5 to the Clubmosses (*Lycopodiaceæ*), 7 to the Horsetails (*Equisetaceæ*), and 4 to the Flowering Plants (*Phanerogamia*). They were, therefore, nearly all flowerless plants (*Cryptogamia*), and produced microscopically minute seeds (called *spores*), contained in small capsules. The trees which now form Swiss forests are not found in the carboniferous strata of Switzerland; yet there were in that country woody plants often attaining a considerable height, which, with the exception of the Ferns, belonged to families now represented only by herbaceous forms, such as the Clubmosses and Horsetails.

Of the former (the *Lycopodiaceæ* or Clubmosses) the Swiss island possessed two principal forms, the *Sigillariæ* (Seal-trees) and the *Lepidodendra* (Scale-trees). The *Sigillariæ* (fig. 1) have pillar-like stems, almost always without branches, and traversed in the direction of their length by numerous furrows. Between each pair of furrows is a ridge, on which large seal-like leaf-scars are arranged in lines, so as to form a regular outline, and to give a very elegant appearance to the stems. It is to the presence of these seal-like scars that the trees are indebted for their Latin name. In the middle of each disk or scar we observe two little warts, between which there is a third smaller one; and these protuberances show where the vascular tissues of the plant passed into the leaf. The dome-like apex of the stem was closely covered with long, stiff, needle-like leaves (fig. 1, *b*), which must have given to the trees the appearance of

Fig. 1.



a. Sigillaria Dournaisii, from Valorcine. *b.* Leaf of *Sigillaria*, from Outre-Rhône. *c.* Fruit-spike of *Sigillaria* (after Goldenberg). *d, e.* Spores at the bottom of the bract. *f.* Spore, highly magnified.

a broom; and at the base the stems often became quadrangular, and were separated into several thick roots, which subdivided into successive forks, and thus often reached a distance of 30 feet from the stem. The roots were closely covered with long, cylindrical fibres, which, when detached, left circular protuberances.

They were formerly separated from the *Sigillariæ* under the name of *Stigmariæ*, and the fibres were mistaken for leaves. Frequently, however, the *Sigillariæ* themselves formed nothing but short dome-shaped stems; and in this *Stigmaria*-form they covered great spaces. Thus we sometimes find whole beds of coal filled with them, which seems to show that, under certain circumstances, these plants might remain for a long time in this almost horizontal state, as is the case at the present day with several Cryptogams and Palms. Probably, as long as the *Sigillariæ* were surrounded by water, they formed these short dome-shaped stems, which, however, shot up when, by the accumulation of mud and mould, more favourable conditions were produced for the perpendicular growth of the plants.

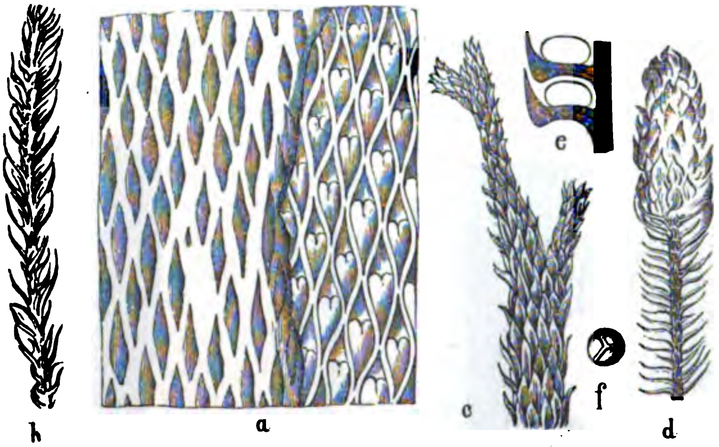
The fruits of the *Sigillariæ* form small capsules, placed at the enlarged base of the bracts (see fig. 1, *d*); many of these bracts are placed close together round an axis, and form a cone (fig. 1, *c*). Even the minute spores are in some cases preserved, and numbers of them are found in the capsules (fig. 1, *f*, highly magnified).

Two species of *Sigillaria* have been observed in the Swiss Carboniferous region. One (*Sigillaria Dournaisii*, Br., fig. 1, *a*) was found in an erratic block from the Valorcine. The leaf-scars are so close as to touch each other, so that the leaves must have formed a very dense tuft at the end of the stem. Of the other species only the roots (formerly called *Stigmaria ficoides*) have been found; this coal-plant, which probably belongs to *Sigillaria alternans* (Lindl.), is very widely distributed both in Europe and America, and has aided materially, under its Stigmarian form, in the production of coal. In Switzerland the *Stigmaria ficoides* is rare; this vegetable has only been met with near Taninge; and the absence of the plant may account for the Swiss anthracite deposits being so thin.

The *Lepidodendra* (fig. 2) are as unconnected with the existing Swiss flora as the *Sigillariæ*, and, like them, they possess a bark of very elegant structure. They look as if their stems were closely covered with regular scales of a rhomboidal, elliptical, or hexagonal form. These scales must be regarded as leaf-pads, and the little rhomboidal protuberance placed at or above the middle of the scale as the place to which the leaf was attached.

From these leaf-scars sprang the long, stiff, linear leaves, forming dense tufts on the smaller branches. At the ends of the branches were the fruit-spikes, consisting of numerous shield-like bracts, the stalks of which, standing perpendicularly from the axis (fig. 2, *e*), bore the fruits, which enclosed numerous small spores (fig. 2, *f*). The stems of the *Lepidodendra* were repeatedly forked, and they attained to a considerable height and bulk. Stems are known 12 feet in circumference and more than 100 feet in height.

Fig. 2.



Lepidodendron Veltheimianum, Sternb. *a*. Fragment of a stem from Outre-Rhône, with the bark peeled off on the left side. *b*. Young branch. *c*. An older branch. *d*. Cone. *e*. Two fruit-capsules placed in the hollows of shield-like bracts, magnified. *f*. Spore, highly magnified.

That these trees adorned the Swiss Carboniferous island is shown by some fragments of stems and branches found in Outre-Rhône and on the Col de Balme. They belong to a species (*Lepidodendron Veltheimianum*, Sternb.) which was spread over all the older Carboniferous district, and associated largely in the formation of coal, both in Europe and America. The tree had a lofty trunk with numerous branches; and the long thin twigs were densely covered with short leaves (fig. 2, *b*). The bark was dotted over with small elongate elliptical scars (fig. 2, *a*); and beneath it the stem was closely set with spindle-shaped protuberances, so that the fragments deprived of bark do not resemble the outside coating. The fruits are borne in small oval cones (fig. 2, *d*, after Geinitz).

Just as the creeping Clubmosses of Swiss forests are to be regarded as the stunted representatives of the *Lepidodendra*, the Horsetails are the dwarfed descendants of the ancient Calamites, some of which were trees of considerable size. Like the Horsetails, they had jointed stems and whorled branches; but instead of the sheaths which in the former closely embrace the stem, they possessed whorls of narrow leaves, forming numerous circles round the long and slender branches. The fruits are not placed at the end of the stem, but form long and generally thin spikes (fig 5, *b*) attached to the twigs. These trees must have had a curious appearance with their jointed and finely ribbed stems and branches and their whorled twigs and leaves. Professor Heer has obtained from Erbignon, Etablon, the Col de Balme, Servoz, and Taninge two species, namely *Calamites Suckowii* (fig. 5) and *Calamites Cistii* (fig. 4). The fragment of the stem

Fig. 4. Fig. 5.

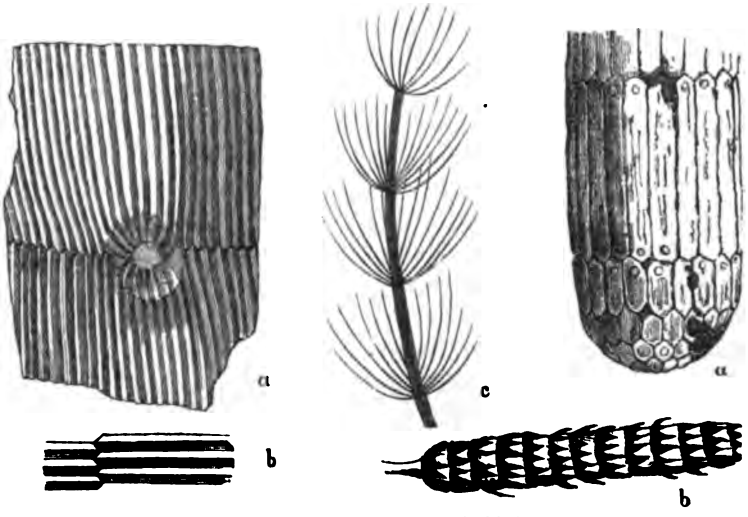


Fig. 4. *a*. *Calamites Cistii*, Br., from Erbignon, half size of nature. *b*. Some of the ridges of the natural size. *c*. A fragment of a branch with the leaves (formerly *Asterophyllites equisetiformis*).

Fig. 5. *a*. *Calamites Suckowii*, Br., base of the stem (after Brongniart). *b*. Fruit-spike.

from Erbignon (fig. 4, *a*) shows very clearly the character of the latter species, in which the ribs of the stem are narrow and raised along the middle into sharp ridges (fig. 4, *b*). The scar at the joint indicates the place where a branch was attached, and the thin twigs with their whorled leaves (fig. 4, *c*) were borne upon the branches. Professor Heer has received such twigs of considerable length from the Mont-du-Fer. The above-mentioned species of *Calamites* are distributed through the whole of the Coal-region of Europe and America, and often occur in great quantities together. They probably lived in low marshy districts. Besides these abundant species, an elegant new form (*Calamites Saussurii*, Heer) is found at Taninge; it is distinguished by its small tufts of leaves and its long thin spikes* (Pl. I. fig. 9, at the end of the volume).

The Calamites are large arborescent Horsetails (*Equisetaceæ*). But herbaceous forms of this type of plants also belong to carboniferous times, and bear the names of *Annulariæ* and *Sphenophylla*. Their jointed stems were thin and herbaceous; and their leaves were whorled, wedge-shaped, and generally notched at the outer margin in the *Sphenophylla* (fig. 8); but in the *Annulariæ* (figs. 6 & 7) undivided, and generally united into a ring at their bases. The fruits (fig. 7 B) were placed in long spikes in the axils of the leaves, and consist of small round capsules. As the branches are disposed in a double row and the leaves all diverge in the same plane, it is probable that these plants lived in water and spread out upon its surface, their long thin stems being certainly incapable of supporting the plant upright.

Annularia brevifolia, Br. (fig. 6), is one of the most abundant plants in the anthracite deposits, and is characterized by its elegant, star-like whorls of leaves; but the long-leaved species (*Annularia longifolia*, Br., fig. 7) is not uncommon, especially at Erbignon and in the Tarentaise. It probably attained a length of several feet, with branching stalks, and rosettes of narrow leaves, from which long spikes (fig. 7 B) burst forth. With these plants is associated, at Erbignon, Outre Rhône, and in the Tarantaise, a *Sphenophyllum* (*S. Schlotheimii*, Br., with the

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* To this we must probably refer the *Asterophyllites delicatulus* of Sternberg.

Fig. 6.

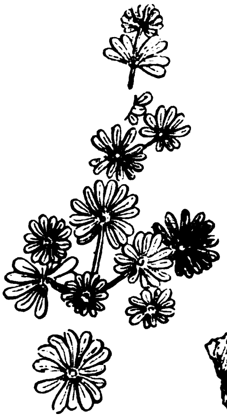


Fig. 7 A.

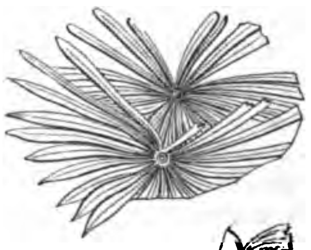
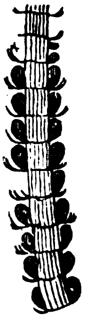
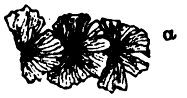
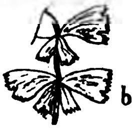
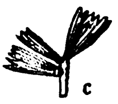


Fig. 7 B.









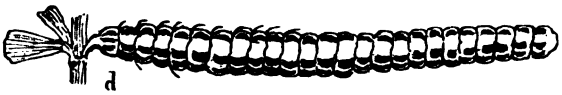


Fig. 8.

Fig. 6. *Annularia brevifolia*, Br. (*Annularia sphenophylloides*, Zenker), from Petit-Cœur.

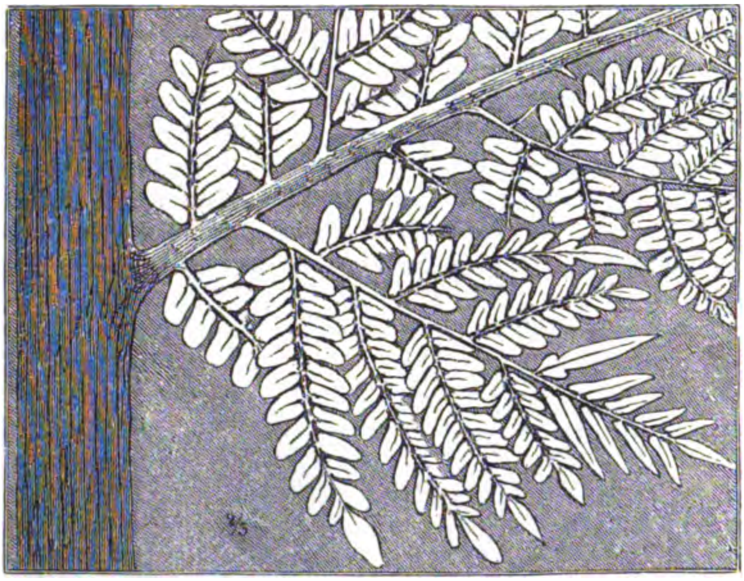
Fig. 7 A. *Annularia longifolia*, Br., from Erbignon. B. Fruit-spike (Germar).

Fig. 8. *Sphenophyllum Schlotheimii*, Br. *a*, *b*, *c*. From Erbignon. *d*. Fruit-spike (Germar).

varieties *Sphenophyllum saxifragæfolium* and *dentatum*, Br.) which occurs here only in small fragments (fig. 8, *a*, *b*, *c*), although in Germany fine specimens and fruits (fig. 8, *d*) have been obtained. The *Annulariæ* and *Sphenophylla* are among the most elegant plants of the Coal-flora; and species similar to the three here engraved have been found also in Germany and America.

The undergrowth and herbage of the Coal-forests seem to have been formed by Ferns, which furnish the principal contingent to the Swiss flora. Many were herbaceous and delicate, such as the species of *Sphenopteris* (*S. tridactylites*, Br., *S. irregularis*, Sternb., Pl. I. fig. 4, and *S. acutiloba*, Sternb., Pl. I. fig. 5) and probably some species of *Pecopteris*; whilst others, such as most species of the genera *Neuropteris* and *Odontopteris*, were probably tree ferns. The most abundant Fern at Erbignon, Posettes, and

Fig. 9.



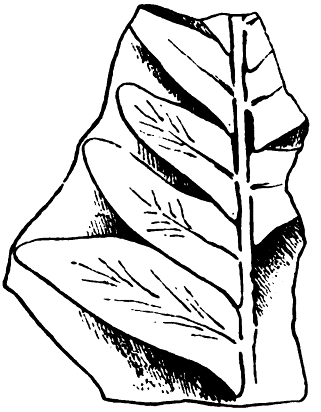
Neuropteris flexuosa, Sternberg, from Servoz.

the Mont-du-Fer near Servoz is *Neuropteris flexuosa,* Sternb., (fig. 9), which is the commonest plant of the Swiss Carboniferous formation. It is also one of the most abundant plants of the American coal-measures, and has been frequently observed in Germany and England. The fronds are very large. From the sides of a rib more than an inch broad, long stalks are given off; and these have lateral branches which support long leaves closely covered with leaflets (fig. 9). Pl. I. fig. 2, at the end of the volume, shows a single leaflet of the natural size. These leaflets stand close together and cover each other at the edges; their width is very variable; but they are always obtusely rounded and somewhat ear-like at the base. The median vein soon divides into delicate lateral veins. The fruits are placed on the back of the frond, and form small oval protuberances, standing in two rows along the median vein (Pl. I. fig. 3, *b*).

Besides the *Neuropteris flexuosa,* nine species of the genus *Neuropteris* have been discovered in the Swiss Carboniferous island, nearly all of which also inhabited North America; so that this genus must have been widely distributed among the coal-plants. Some of these *Neuropterides* are nearly allied to the preceding species, such as *N. gigantea,* Sternb., and *N. Leberti,* Heer (fig. 10), from Erbignon and Mont-du-Fer; while others are more distinct, having their leaflets rounded and much smaller, like the widely distributed *N. Loshii,* Br., and the elegant *N. microphylla,* Br., of which the tip of a very fine frond from Erbignon is shown in Pl. I. fig. 3, at the end of the volume.

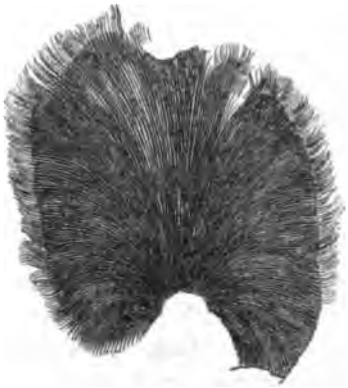
The Ferns of the genus *Cyclopteris* are very like those of the *Neuropteris;* but in them the veins radiate over the leaf, and no strong median vein is to be seen. One of the largest species is the *Cyclopteris auriculata,* with doubly pinnate fronds and obtusely rounded leaflets (Pl. I. fig. 6), which are sometimes nearly circular (Pl. I. fig. 6, *b*), sometimes elongate ovate and of a considerable height (Pl. I. fig. 6, *a*). This species, which is widely distributed among coal-plants, has been several times found at Taninge. The fringed *Cyclopteris lacerata* (fig. 11), from Erbignon and Servoz, is one of the few species which seem to be peculiar to the anthracite deposits. Its occurrence in Switzerland is of great interest, as hitherto it had been supposed that the *Cyclopterides* with fringed leaves belonged exclusively to

Fig. 10.



Neuropteris Leberti, Heer, from Mont-du-Fer.

Fig. 11.



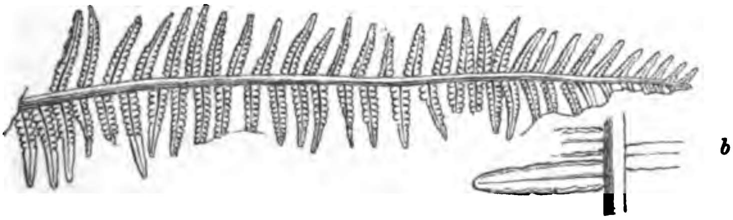
Cyclopteris lacerata, Heer, from Mont-du-Fer.

the American coal-measures. The leaf is kidney-shaped, traversed by numerous close veins, and delicately fringed at the margin.

Odontopteris is another nearly allied genus, one species of which (*Od. Brardii,* Br.) has magnificent fronds, attaining a length of about 3 feet. Its long pinnæ, with their sharply cut leaflets (Pl. I. fig. 1), form beautiful designs, white like silver, on the shales of Outre-Rhône, the Col de Balme, and Petit-Cœur. Of a second species (*Odontopteris alpina,* Sternb.), first discovered on the Stangalp in Styria, Professor Heer possesses fragments brought from Erbignon and the Col de Balme; it occurs also at Petit-Cœur and in Saxony, and in the anthracites of Pennsylvania.

The preceding Ferns have no representatives in the flora of the present day; their generic types are extinct. The *Pecopterides* of the Swiss Carboniferous island, on the other hand, remind us of the *Cyatheæ,* the arborescent Ferns which inhabit tropical regions. This is the case especially with *Pecopteris cyathea,* Schl., and *P. arborescens,* Schl. (Pl. I. figs. 7 & 8), which occur in abundance at the Col de Balme, and are distributed widely in the Carboniferous deposits both of the Old and New World. These *Pecopterides* probably had large stems, at the summit of which the long tripinnatifid fronds must have constituted an elegant crown. A small fragment of a branch bearing two pinnæ with their leaflets is shown in Pl. I. fig. 7; many of these branches were attached to a common stalk, and a great number of such stalks were united

Fig. 12.

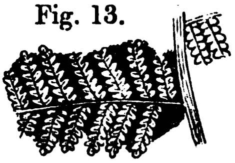


Pecopteris Lamuriana, Heer, from Lamure. *b.* A leaflet enlarged, showing the spore-cases.

to form a vast frond. In this way there must have been produced a fern-foliage, such as we have endeavoured to represent by the tree ferns in the middle distance of our ideal Carboniferous landscape.

Very like these *Pecopterides* is a fine species which occurs abundantly in Lamure, and is distinguished by its remarkably long, narrow, and finely divided leaflets (*Pecopteris Lamuriana,* Heer, fig. 12). *Pecopteris dentata,* Br., has also a very elegant and finely divided frond, of which a small fragment is represented in fig. 13. Magnificent fronds of this species have lately been found at Erbignon; they evidently belonged to arborescent forms. The stalk of the frond is more than 2 inches thick, and the leaves are twice divided into lateral segments with long leaflets.

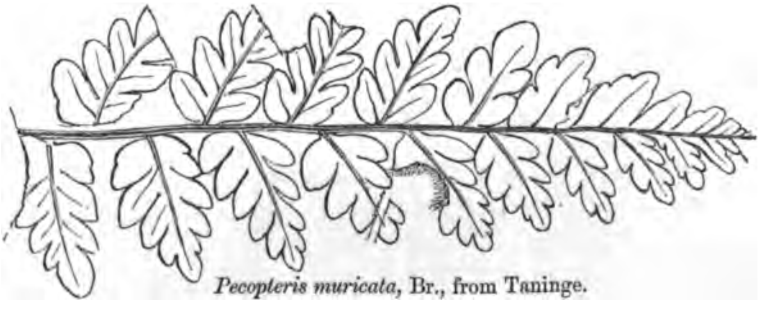
Fig. 13.



Pecopteris dentata, Br., from Taninge.

Besides these ferns with delicate indentations, the Swiss Carboniferous flora includes broad-leaved forms which remind us of some tropical Polypodies; one of these is the *Pecopteris muricata,* Br., a fragment of which is represented in fig. 14.

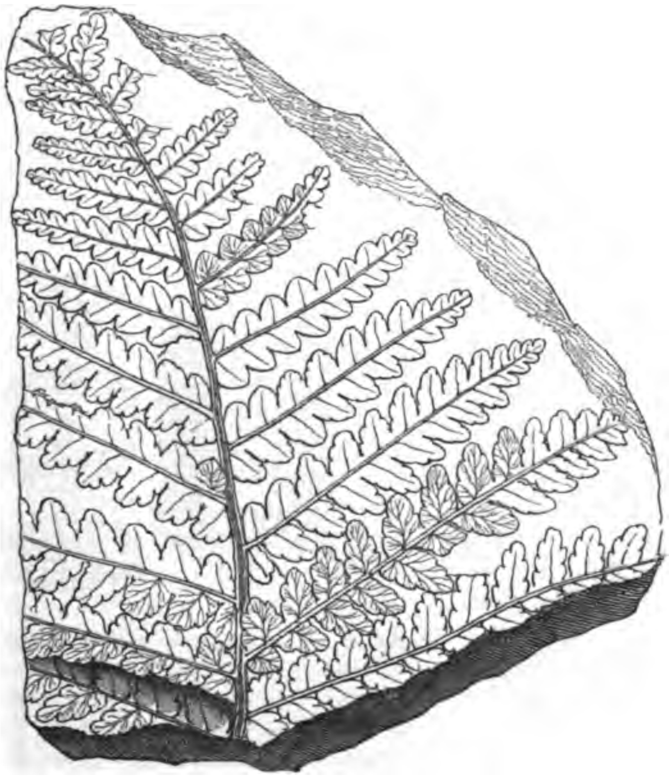
Fig. 14.



Pecopteris muricata, Br., from Taninge.

Fig. 14 B represents a small fragment of a magnificent frond of *Pecopteris Pluckenetii,* Schl., showing the extremity of one of the lateral pinnæ. This species forms beautiful brilliant silvery impressions upon the laminated rocks at the Grand-Châble (Outre-Rhône in the Valais); it is also often met with in Germany and France.

Fig. 14 B.

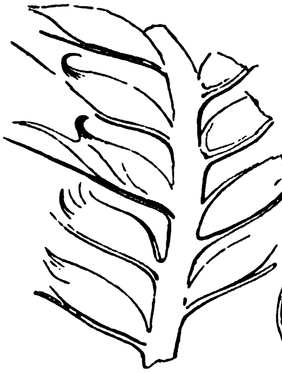


Pecopteris Pluckenetii, Schl., from the Grand-Châble.

To these flowerless plants Professor Heer only adds four species, which probably belong to the Phanerogamia, although they differ so much from all existing types of plants that their position in the system is still doubtful.

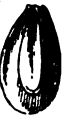
The most abundant species probably belongs to the Cycadeæ, of which it probably forms, with the *Næggerathiæ*, a peculiar group, the first indication of the Gymnosperms. It has been dedicated to the memory of the distinguished naturalist Corda, who disappeared fifteen years ago, during a journey of discovery in South America. The Swiss species (*Cordaites borassifolia*, Sternb.) was rather plentiful at Erbignon, Outre-Rhône, Servoz, and Taninge, and in the Tarantaise, where it forms on the stones broad, finely striated, silvery bands (fig. 16, *a*). At the base these long leaves embraced the stem like a sheath; and they were brought together into a crown at its summit. In their aspect they resembled the living *Dracænæ* and Yuccas, and they are so represented as broad-leaved bushes in our ideal landscape. The seeds (fig. 16, *c*, *d*, from the allied *Cordaites principalis*) are rounded and of considerable size, resembling those of the Cycads.

Fig. 15.



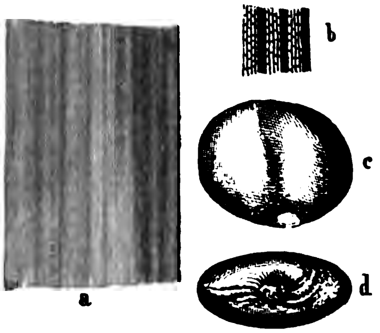
Antholithes Favrei, Heer, from Posettes.

Fig. 15 B.



Rhabdocarpos Candollianus, Heer, from Taninge.

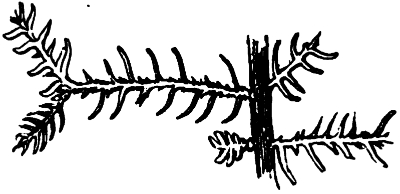
·Fig. 16.



Cordaites borassifolia (Sternb.).
a. Fragment of leaf, from Taninge.
b. A portion of the same, magnified.
c & *d*. The seed of *C. principalis*, Gr. (after Geinitz).

The fruit from Taninge, represented in fig. 15 B (*Rhabdocarpos Candollianus*, Heer), probably belongs to a tree of this family, perhaps a *Næggerathia*; and the Coniferæ are represented by a species of *Walchia* (fig. 16 B), a genus the general aspect of which resembles that of the *Araucariæ*.

Fig. 16 B.



Walchia piniformis, Sternb., var. ?, from Posettes.

An inflorescence from Posettes (fig. 15) belongs to a more highly organized plant, probably a Monocotyledon. The flowers form a spike, and are seated in the axis of needle-shaped bracts; they seem to have a calyx with lobes, the segments of which are turned back. This inflorescence and another found in the English Coal-measures (*Antholithes Pitcairniæ*, Lindl.) resemble the *Pitcairniæ* of tropical America, which are attached to the trees, and grow suspended in the air.

When we compare the floras of the above-mentioned different localities, we find that those of the district stretching from the Bas-Valais to Petit-Cœur, near Moutiers, exhibit a close agreement in their plants; we notice in them especially the same species of aquatic and marsh plants (*Annulariæ, Sphenophylla,* and Calamites). Perhaps a lake extended in this direction, in the waters of which the *Annulariæ* and *Sphenophylla* grew, while its marshy shores were clothed with Ferns, among which *Neuropterides* and *Pecopterides* predominated. The former are mostly found in the Valais and Chamouni, the latter in the Tarentaise. The flora of Taninge differs from these considerably. The commonest species here are *Sphenopteris acutiloba,* a *Pecopteris* with wide-spread pinnæ and broad lobate pinnules (*P. muricata,* fig. 14), and *Neuropteris auriculata.* Nevertheless this flora has 9 species in common with the rest of the anthracite flora, and 14 with the coal flora, so that, on the whole, it undoubtedly belongs to the same period.

If we bring together the Carboniferous plants of Switzerland into a general group, it is not difficult to obtain an idea of the aspect of the land of that period; and the accompanying Plate may serve to aid the fancy. In it we have endeavoured to represent the principal types of the Swiss Carboniferous flora as they appeared in life. The Ferns in the left of the foreground represent *Odontopteris Brardii,* and the tree with furcate branches and those to the left in the background *Lepidodendron* (*Sagenaria*) *Veltheimianum*; the short-stemmed bushes with large tufts of leaves show *Cordaites borassifolia,* the trees in the middle distance *Pecopteris cyathea,* and those in the right corner a group of Calamites with some *Sigillariæ*; in the water float the leaf-stars of the *Annulariæ* and a young *Sigillaria* (*Stigmaria*). This group shows us scarcely any thing but flowerless trees, the bark of which had a peculiar ornamentation. They were by no means larger than the trees of our present forests; but as they belonged to families which now include only herbaceous forms, this flora has a very peculiar and unfamiliar aspect. The deciduous trees and Conifers of which our existing forests consist were wanting; but the Club-mosses, Ferns, and Horsetails which now grow as lowly herbs in the shadow of the woods, then shot up into trees, and waved their foliage in the air. The soil was moist and marshy, and here and there covered with water, upon which the *Annulariæ* and *Sphenophylla* displayed their delicate leaf-whorls; whilst the Stigmarian forms of the *Sigillariæ* with their long roots formed great floating nets, on which Calamites and Ferns gradually collected, and enabled the *Sigillariæ* also to shoot up into great stems.

This vegetation was luxuriant but very uniform; it was composed of but few forms of plants, and was destitute of the ornament of flowers. There is a monotony about this picture of the Coal period. Not only were flowering plants almost entirely absent, but there were none of the higher animals: no birds rested on the branches of the trees; and no mammal enlivened the depths of the forests. The air was sultry and full of vapour, the soil hot and steaming; and the stillness was profound, broken only by the plashing of the rain, or the whistling of the wind as it passed by the leaves of the trees! The earth was probably covered by a dense envelope of clouds; for from the high temperature of the soil there must have been much more water in the air than at present; and in consequence of this, the terrestrial climate did not depend only on the sun, but was much influenced by the high temperature of the globe. To this hypothesis we are also led by the fact that at that time the same forms of plants existed even in the extreme north.

In the summer of 1868 the Swedish naturalists Nordenskioeld and Malmgren discovered in the coals and neighbouring rocks of Bear Island (lat. 74° 30′ N.) 18 species of plants, 15 of which are identical with those of the lowest Carboniferous deposits. The early Coal-flora of Bear Island has characters identical with those of the Vosges and the Black Forest. It includes abundant *Lepidodendra* (especially the *L. Veltheimianum*), *Knorriæ*, and Calamites (*C. radiatus*, Brgn.). Under the shade

Buri & Jeker

[illegible]

of these trees lived Ferns with large fronds (*Cardiopteris frondosa* and *polymorpha*). The same kinds of *Lepidodendron* and *Calamites* have been found in Spitzbergen (Klaas-Billen Bay). The flora of the Parry Islands seems to have had the same aspect: numerous deposits of coal have been found there; and among the few plants discovered at Melville Island (Bridport Bay, lat. 75° N.) is the *Knorria acicularis*, which has also been indicated at Bear Island, and is met with in the Silesian coal-measures. These localities belong to the most ancient deposits of the carboniferous period; but M. Nordenskioeld has discovered recently (1873) at Robert River, Research Bay, lat. 76° N., in Spitzbergen, a later carboniferous flora.

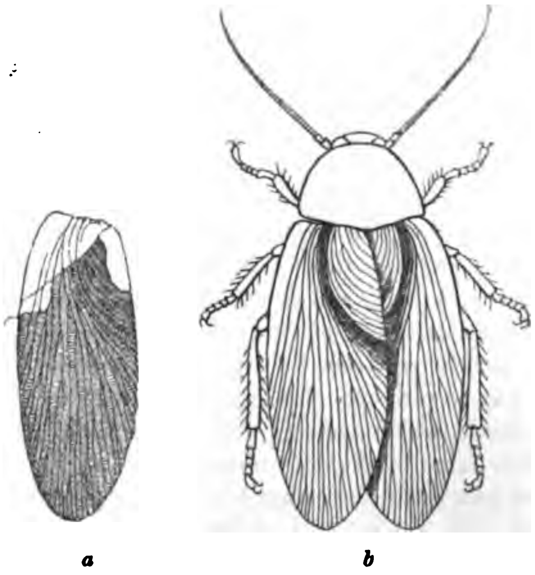
The arctic marine fauna has the same character. Many species of Mollusca from the sea of the Carboniferous period in the Arctic zone are found also in the same formation in Europe, and some even in the tropics. Thus *Spirifer Keilhavii*, Von Buch, has been collected in Bear Island, in Spitzbergen, in North-Albert Land, in Petschora and elsewhere in India; *Productus costatus*, Sow., in Spitzbergen, Russia, England, North America, India, and Australia; and *Productus Humboldtii*, D'Orb., in Spitzbergen, Russia, and South America. In like manner *Productus sulcatus* has been observed at Melville Island (lat. 76° N.); and *Spirifer cristatus*, Schloth., has been found at Spitzbergen and has a vast area. Besides these Mollusca, Spitzbergen furnishes Corals, which are met with at Klaas-Billen Bay (lat. 78° 40′ N.) in large blocks of limestone.

All these facts go to prove that at that time the preponderant heat on the earth was not that of the sun. The polar zone must therefore have enjoyed a much higher temperature than at present; and the presence of the same species under latitudes from 40° to 76° N., seems to indicate that there was a great uniformity in the temperature of the globe. On the other hand, the general character of the Coal-flora reveals a marshy soil and an atmosphere charged with vapour; and it is only in the moist tropical shores that we now meet with vegetable forms at all approaching it.

It is to be observed that the Ferns and Club-mosses of the present day live generally in the shade, and have much less need than the flowering plants of the direct rays of the sun. Shade, no doubt, was also suitable to their early ancestors; and as these form the great majority of the Coal-plants, we can understand that they may have flourished under a constantly clouded sky. A similar climate favoured the few known insects of the period, which are chiefly nocturnal, such as Termites and Cockroaches.

The Carboniferous rocks of Switzerland furnish a species of Cockroach, the most ancient Swiss fossil animal with which we are acquainted. Prof. Heer discovered a wing of this insect at Erbignon, side by side with remains of leaves. This species is of the same size as *Panchlora Maderæ*, Fab., which inhabits not only Madeira, but also Africa, tropical America, and India. The Swiss fossil is characterized by the numerous strong nerves of the wings and the fine and very close transverse nerves. It differs from the living species by the curvature of the anal nerves directed towards the inner edge of the wings, and resembles the species from Carboniferous rocks.

Fig. 16 c.



Blatta helvetica (Swiss Cockroach), Heer, from Erbignon.
a. Wing, of the natural size. *b.* The animal restored.

The very wide distribution of Carboniferous plants was probably dependent on climatic conditions. The species discovered in Switzerland nearly all agree with those of the rest of Europe, so that the flora of the whole of Europe at that time was mirrored in the little Swiss Carboniferous island. Thus the Swiss Flora, poor as it is in species, gives us a true picture of the Coal-flora in general. Nay, even in America we find the same plants; and in that continent about 300 species of Coal-plants are now known, about half of which occur also in Europe; and the peculiar American species are almost all mere repetitions of European forms.

The explanation of this remarkable fact is not difficult. The flora consisted everywhere chiefly of flowerless plants, which have exceedingly minute seeds; and these would be readily carried away by the wind, to develop themselves wherever they met with a favourable position for life. Exactly the same development takes place at the present time. Lichens and Mosses, and also Ferns and Horsetails, are very widely distributed; and many of them are scattered over the whole earth. If we consider that, according to Ehrenberg, Infusoria and Diatomaceæ are carried by the wind from Tropical America to Germany, and that the spores of the Vine-pest (*Oïdium Tuckeri*) and Potato-fungus (*Peronospora infestans*) have been spread by the air over the whole of Europe and into the Atlantic and Greek islands, it will seem by no means incredible that the spores of Cryptogamic plants were scattered over whole continents in the Carboniferous period.

The American bogs include chiefly the same species of Cryptogamic plants as those of Europe, whilst the flowering shrubs and trees of these peat-bogs are quite distinct. But as in the Coal period the woody plants were Cryptogamic, the conformity of the vegetation of the two hemispheres, which is now limited to the smallest plants, then comprised trees; for they had at that time microscopic spores easy of transport by the wind, whilst flowering plants always possess much larger and heavier seeds. Moreover the naturalization of new plants meets with fewer obstacles if there are but few species with which they have to compete for the possession of the soil, and if there are also not many animals to which they serve as food; and in both these respects the Carboniferous period enjoyed advantages for wide areas of distribution of plants.

This uniformity of the organic world proves that climatic conditions were then very uniform, and that the present differences of zones did not exist. At the same time it indicates that the duration of the Carboniferous period must have been immense, as the wide distribution of its plants and the production of so uniform a flora must have required a long space of time. This view is confirmed by the formation of coal, for which we are indebted to these plants, and which is so important that we must treat it in some detail in order to explain how this fuel was produced and how it reached its present position in the earth.

When we examine the *anthracite* of the Valais, or the *coal* which reaches us in such quantities from Saarbrück, or even the *lignite* which occurs near Käpfnach, at Hohe Rhonen, at Rufi near Schännis, at Paudèze near Lausanne, and in many other Swiss localities, we have some difficulty at first in realizing that these substances belong to the vegetable kingdom. They seem to consist of a uniform black or brownish-black mass, which shows no trace of vegetable structure to the naked eye, so that it is easy to understand why it was formerly regarded as a mineral substance. More careful examination shows that it is a vegetable product; for not only do we find well-preserved plants in the rock between the beds of coal, but a vegetable structure may often be detected in these beds. The chemical composition also shows that coal originated from accumulations of plants, from which most of the oxygen and hydrogen have been gradually eliminated, most completely from anthracite, and in a less degree from lignite. Leaving out of consideration the mineral constituents of the ashes, coal, peat, and wood consist of three elements—namely, carbon, oxygen, and hydrogen, which occur in the following proportions:—

	Carbon.	Hydrogen.	Oxygen.
In wood	52·65	5·25	42·10
In the peat of the Katzensee . . .	56·60	43·40	
In paper-coal	64·16	35·84	
In lignite from Elgg (canton of Zurich)	67·00	4·8	28·2
In lignite from Herdern (canton of Thurgovia), according to Pettenkofer	66·41	5·46	28·13

	Carbon.	Hydrogen.	Oxygen.
In lignite from Wirtatobel, above Bregenz (mixture from six carboniferous schists analyzed in the chemical laboratory at Zurich) . . .	73·08	5·03	21·89
In the coal of Käpfnach (canton of Zurich)	71·08	5·03	22·09
In the coal of Corbeyre	90·50	5·05	4·40
In the anthracite of Swansea (Wales)	94·04	3·38	2·58

It was formerly supposed that coal and lignite were produced from masses of wood swept together by water. The notion was that, in lake-basins and in the sea, at the mouths of great rivers flowing through forest-clad countries, vast masses of wood were accumulated, and, sinking to the bottom, were covered with mud, when, being pressed together more and more by the weight of succeeding masses, they became converted in the course of thousands of years into lignite and coal. In support of this view the delta of the Mississippi has been cited, as in the outlet of that river, at times, great masses of the trunks of trees are accumulated, so as to cover a surface of many square miles to a depth of several fathoms. In lakes and the side-bays of large rivers uprooted trees are sometimes brought together in great quantities; and such masses of wood, sinking to the bottom and increased annually for hundreds and thousands of years, may have contributed to the production of lignite. The deposits at Bovey Tracey, in Devonshire, which Prof. Heer examined in the autumn of 1861, are very instructive in this respect. The lowest beds consist almost entirely of trunks of trees, which for the most part still exhibit a woody structure and yearly circles, and are only converted here and there into black lignite. There is no indication that marsh-plants contributed in any way to the formation of this lignite-bed. But beds of lignite and coal have rarely been formed in this manner, and in Switzerland Prof. Heer knows of none that can be so explained. Thin bands of coal are often met with evidently derived from the stems of trees sunk in the mud and carbonized, as in the sandstones of Bäch and Bollingen, in the liassic marls of Schambelen, in the Keuper or Upper Triassic rocks of the canton of Basle, &c.; but trunks of trees nowhere form important accumulations of coal. All the Swiss lignite and anthracite deposits, like all the larger and more wide-spread coal-deposits, must have been produced in another way. According to Unger's calculations one metre of coal presupposes a layer of wood 8·76 metres thick; but we know of beds of coal 30 metres thick, which, therefore, must represent 263 metres, or a perfect mountain of wood. Over a small space this might occur; but in the case of thick deposits of coal stretching over wide regions, we cannot see whence such enormous masses of wood could be derived. The most striking evidence is the nature of the plants which are found in the coal and the surrounding rocks. These show us that *peat-mosses* have been in all times the sources of the coal masses. From them we obtain the most important information as to the history of the formation of coal; and therefore we must study them in order to obtain a notion of the process by which nature has laid up in the earth such incalculable stores of carbon.

All organic life commences with excessively minute structures, which are continually reproduced in inconceivable numbers. On land the Lichens first appear on rocks and the bark of trees, covering them with coloured spots and bands. The Mosses follow, and prepare the hard rock for the reception of higher plants. Water, even when apparently quite pure, is full of the germs of minute plants and animals, which possess an enormous power of multiplication, and soon swarm in the water by millions. Thus, in lakes and ponds a world of little organisms is produced; and of these, countless swarms die yearly, and form a layer of organic matter at the bottom of the water. But in running water this deposit is carried away; and even in lakes and ponds, with a permeable bottom and constant renewal of the water, the accumulation of organic matter is prevented. When, however, the ground becomes impermeable and the water stagnates, the case is altered. The formation of an impermeable ground is the work of small mollusca, which live in the water in great abundance. After death their shells decompose, and gradually produce, with the inorganic deposits of the water, a sort of calcareous loam, called *blanc-fond* (white ground) in Neuchatel, and *lake-chalk* in the canton of Zug; the latter is a suitable name, which we may adopt. It is only when the mollusca have given origin to this impermeable layer, and thus in a manner cemented (or *puddled*) the ground, that the quiet deposition of the organic mass can commence. It becomes the parent of new and more highly organized structures. The Algæ are followed by floating mosses, which accumulate in the water; and, as each of their capsules may contain a couple of millions of spores, they increase very rapidly, and thus, notwithstanding their small size, may soon produce an enormous quantity of organic substance. Then come the flowering plants, the Utriculariæ, Potamogetons, and Myriophylla, which plunge their roots into the bottom, and rise to the surface to flower; but these sink again beneath the surface to ripen their seeds; the Water-Lilies also appear, which float with their broad leaves upon the surface, and form, with the Duckweeds, a green covering for the water. Reeds advance into the pond from the shore, and, with numerous Sedges, Horsetails, Rushes, and other plants, interlace into a dense matted collection of roots, which gradually spreads over the whole pool. Thus, by degrees, a firmer covering of the ground is produced, and upon it a number of beautiful bog-plants take up their abode: no water is to be seen; but the pool is filled with organic matter. Frequently, however, the superficial matted covering is so thin that men and large animals venturing upon it break through, and sink into the black mud beneath, or even, if it is capable of bearing the human weight, the ground shakes under the feet, and allows the water to ooze up from below. The formation of peat is constantly going on in the soft mud beneath the covering of the pond: continual additions of dead vegetable matter, protected from the direct action of the air, are slowly decomposed, and thus gradually convert the liquid mud into a solid body of peat. But vegetation also increases, in which the Bog-moss (*Sphagnum*) is found, either in the water or attached to the roots of large plants; this moss draws up muddy water from the bottom of the pond, and, with dew and rain, maintains the humid nature of the soil. On its soft moist cushion grow the Water-trefoil with its white-fringed flowers, the Cranberry, and the Andromeda; and the Sundew (*Drosera*) is seldom absent. When the surface becomes firmer, woody plants make their appearance, first represented by the Heath (*Erica vulgaris*) and the Creeping Willow (*Salix repens*). Among trees the Birch is the first to appear, and then the Pine; and among large bushes are seen the Buckthorn (*Rhamnus frangula* and *catharticus*) and the Alder. Here and there a Fir tree ventures to show itself; but it never thrives, and even Pines do not rise to their ordinary height. As soon as trees attain a certain size and weight they sink down and become converted into peat, like the herbaceous vegetation. Trees are also easily blown down by the wind; and hence the upper part of the peat is often filled with the trunks of Pines and Birches, which adds greatly to its value as fuel. In the higher regions (as near Einsiedlen and in the great moors of Rothenthurm) the Mountain-Pine (*Pinus montana uliginosa*) grows over the peat-bogs, and in some places covers them with an almost impenetrable thicket.

Peat, therefore, is formed partly by Mosses, partly by the roots and débris of marsh- and water-vegetables, and partly by woody plants. The more solid parts of the trees are preserved, and are found even in very old peat, whilst the softer herbaceous portions are converted into a liquid vegetable pulp. Here and there the decomposed plants form a brown pasty substance (dopplerite*), which by drying becomes hard and brittle. This substance generally occurs in small deposits or veins, but sometimes in larger masses, as in the peat-bogs of Gonten and Oberburgen. It gives a compact peat, which produces much heat.

As long as the covering of a peat-bog is but little developed it forms a flat surface; but by growth it may rise in time above the surrounding land, so as to form a high moor, which sometimes attains a very considerable size. It then receives its moisture only from dew and rain, which it sucks up like a sponge, and retains for a long time, giving the moisture off again in the form of vapour. Thus it is always surrounded by a vaporous atmosphere, which favours the growth of its vegetation.

Marshes in low situations often receive water from other sources besides the rain and dew; such peat-bogs are frequently formed in the neighbourhood of gently flowing rivers (as in the basin of the Glatt), and also on the shores of lakes. The Katzensee near Zurich, and the lake of Pfäffikon, are surrounded by peat-mosses; and this latter piece of water shows how the peat in its growth has gradually lessened the borders of the lake. At the outlet of the Aa rivulet from lake Pfäffikon (near Robenhausen) there is now a large peat-moss.

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* See Prof. F. J. Kaufmann on dopplerite, peat, coal, &c.

That the place of this moss was once occupied by the lake is proved by an examination of the subsoil; for the peat rests upon the lake-chalk, which contains the remains of innumerable lake-Mollusca (bivalves, univalves, *Unio pictorum*, *Anodonta anatina*, and *Lymneus*). Above the lake-chalk are found, here and there, many remains of a lacustrine colony formerly established on piles near the shore of the lake. The layers which contain these remains are covered by a bed of peat, from 5 to 7 feet thick, which must have been formed subsequently, and which has forced back the waters of the lake.

The results obtained by M. J. Messikomer by numerous diggings in the deposits of Wetzikon, and of the valley of the Aa, give the following section of this district:—

Postdiluvial.	1. Vegetable mould, about 1½ foot thick.
	2. Peat, 5–7 feet thick, traversed in one place by a band of loam.
	3. Loam, ½–1 foot thick.
	4. Remains of lacustrine habitations about 1 foot thick, containing carbonized apples, grains of corn, woven tissues and mats, implements, weapons, &c.
	5. Lake-chalk, with freshwater Mollusca.
Diluvial.	6. Diluvial débris, 10–12 feet thick.
	7. Paper-coal, 1–5 feet thick.
	8. Lake-chalk, ½ foot thick.
	9. Gravel.
Miocene.	10. Sandstone (*Molasse*), 4 feet.
	11. Lignite and marl, 4 inches.
	12. Sandstone (*Molasse*), 4 feet.

The piles bearing the floor on which the lacustrine huts were erected are driven through the lake-chalk; and as carbonized fruits and seeds of useful plants, and the bones of domestic animals kept by the lake-settlers, rest immediately upon the lake-chalk, these remains must have fallen to the bottom of the lake before the formation of peat had commenced. A portion of the peat, however, was formed while the settlement still continued here; for traces of human occupation occur in the lower layers of the peat. A temporary inundation stopped the formation of peat; for in the eastern part of the moss we find a bed of loam in the peat, the occurrence of which can only thus be explained.

A high moor has not been formed in this locality, although the development of the peat-moss began more than 2000 years ago, since the pile-village of Robenhausen belongs to the stone age. The perfect preservation of the fruits, which had not been carbonized, of the fibres of flax and the lime-tree, and even of the leaves of the beech and of delicate mosses, found here, shows clearly the great preservative power of peat-mosses. This depends chiefly upon the ulmic acid, which is continually generated by the decomposition of vegetable matter, and, not being carried away by running water, works without hindrance in the production of peat.

On the Pfäffikon lake, the Katzensee, and many other small Swiss lakes the formation of peat has commenced under water, and it has taken centuries, or even thousands of years, for it to advance far enough to allow forest vegetation to appear. Sometimes, however, the forest may precede the peat.

When by any chance the outflow of water from a forest is prevented or seriously impaired, it collects in the hollows, in which the aquatic vegetation and the formation of peat commence at once. In this way the forest peat-mosses are formed. The surrounding trees are injured in their growth and gradually die; and when they are uprooted by the wind no fresh aftergrowth succeeds them. The old forest laid low is thus converted into peat-soil, in which the trees are the first foundation of the peat, and assist in its formation, whilst the mosses, sedges, and marsh-plants in general make the principal part of the vegetable mass. When the peat has attained a certain thickness, Pines and Birches will again invade it, as in the case of the mosses already described. A fine example of the presence of large trunks of trees at the bottom of a deposit of peat is to be seen in the vicinity of Zurich, near the lake of Pfäffikon, in the marsh of Unterwetzikon, which a few years ago was divided by the railway, and which is only a mile from the remains of the lake-habitations of Robenhausen. Below 9 feet of peat in this marsh trunks of trees are found prostrate in all directions, some of them being 80 or 100 feet in length. The existence here of an ancient forest is proved by the fir-cones and hazel-nuts discovered in a good state of preservation.

Peat owes its formation principally to the following causes:—

1. Stagnant water protects the vegetable matter in it from the contact of the air; decay advances very slowly, and a large portion of carbon remains in the ground.

2. Lake-chalk assists largely in carpeting the bottom of a pond with an impermeable layer, which constitutes a basis for the quick formation of organic deposits. This layer of lake-chalk occurs in all peat-mosses both in Europe and in America*, being everywhere formed from the remains of small aquatic animals.

3. Acids are disengaged during the decomposition of plants which remain in stagnant water, and are termed "ulmic acids;" but mineral subtances must not preponderate in the water, or the effect of these acids would be neutralized. Resinous substances also aid in the preservation of peat, especially where the trees under decomposition belong to the genera of pines and birches.

4. *Plants* adapted for the formation of peat must be produced in the marshes, so that, when favourable conditions exist, gases may be absorbed from the air and carbon condensed and deposited on their leaves, stems, and roots, a heating-power being communicated to peat by carbon.

As these conditions of the formation of peat have always existed, peat-mosses were formed and increased at all periods of the world's history as at the present day. But great changes have occurred in the oldest peat-mosses, and by these the aspect of the peat has become materially altered. At Wetzikon, scarcely a mile from the moss containing the pile-village, there is a bed 12 feet thick of clay and pebbles, and beneath this occurs a layer of old peat, which in one place attains a thickness of 5 feet; at Dürnten, about a mile from Wetzikon, there is a similar deposit of old peat here and there, 12 feet in thickness, beneath about 30 feet of rolled pebbles and sand; and at Utznach a still larger deposit of old peat has been worked for many years.

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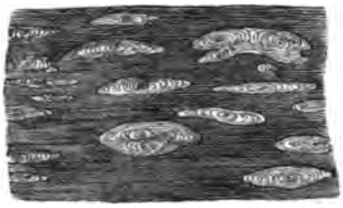
* See Lesquereux, Palæontological Report of Kentucky, p. 508. He calls the lake-chalk "the white clay of the bottom," and shows that the bottom of the Great Dismal Swamp and its peat-lakes is coated with it.

This form of old peat, known as *paper-coal*, is of considerable importance as fuel. That it originated from peat is certain. The coal-deposit at Dürnten by no means consists of a homogeneous mass. Its basis is a greyish-white loam containing numerous shells (*Anodonta*, *Valvata obtusa*, *V. depressa*, and *Pisidium obliquum*), which here represents the lake-chalk of the Swiss peat-mosses; and the coal-deposit itself is traversed in its thickest part by six bands of a dark earthy substance, becoming grey when exposed (and therefore called "silver" by the workmen), which is not combustible. For the purposes of fuel the mass between these earthy bands can alone be employed. In the lower stratum there are many fragments of wood and fir-cones, which occur both at Dürnten and Utznach, and are not found in the upper stratum, which is characterized by layers of mosses closely interwoven into a compact mass and traversed by reeds and roots. The reeds lie at the basis of this stratum, and are covered by trunks of trees prostrate in all directions and showing roots, bark, and wood. The trunks are seldom thick, and they are pressed flat, their length being from four to eight times their breadth (fig. 17). The annual circles of growth are often still visible; and in some Prof. Heer was able to count about 100 circles. As in peat, these trunks are surrounded by a blackish brown mass, which was undoubtedly produced from the decayed herbaceous organs of plants, and once probably formed a pasty substance. In each stratum the same disposition of parts is repeated; but in the uppermost bed there are fewer trunks of trees, and mosses and reeds predominate.

Fig. 17.



Section of a piece of Paper-coal from Dürnten. Much reduced.

This description of paper-coal beds agrees exactly with the progress of the formation of peat, which becomes still more apparent when the plants of the paper-coals are submitted to a closer examination, showing that the mosses which have taken an important part in the formation of the paper-coal are of the same kind as those of the peat; the rushes and reeds also indicate a marshy soil; and the long portions of the stems creeping horizontally between the leaf-buds prove that the soil was soft and loose, whilst the numerous seeds of the Water-trefoil scattered in the coal tell us that it was of a peaty nature. Of trees, there are firs, pines, and birches; the firs are only in the lowest stratum, whilst the pines and birches are found in all the strata. Trunks and branches of pines are found, but rarely with leaves; the birch-trunks are partly covered by their white bark, which may be here and there unrolled. The peat-marshes comprise many pines and birches. The paper-coals and their loams contain the remains of some animals which formerly lived in the peat-moss, and of others which have come there by accident. Among the former are the snails and aquatic shells found in the lake-chalk, and the Marsh-Beetles (*Donaciæ*), which are sometimes so abundant in the coal that their blue and horny wing-cases sometimes cover large spaces. These lived, no doubt, on the aquatic plants, like the *Donaciæ* of the present day. Other animals have wandered into the bog and been drowned or suffocated there; such are the larger mammals, which will be referred to in a future chapter (Chap. XII.).

Paper-coals are remarkable from the peat in their composition having been pressed and dried. The peat-presses consisted of enormous masses of rolled pebbles, which cover these beds; and, without doubt, the trunks of trees and the surrounding peaty mass were still quite soft when the superincumbent strata were accumulated over them, so that they were easily compressed and reduced to the flattened form in which we see them. The reeds also were pressed to such an extent that they now appear as bands no thicker than paper; and the mosses are crushed into a dense and nearly compact substance. The paper-coal, consequently, is pressed and dried peat, and was not formed from floating timber brought together in heaps and piles.

The paper-coals always lie *under* the beds of rolled pebbles, but *above* the sandstone of Switzerland. Between the strata of sandstone we find the *lignites* (brown coals), which are consequently lower than the paper-coals, and belong to an older period. In the section at Wetzikon (p. 27), the rolled pebbles are immediately above the soft sandstone (molasse) which forms the hills in the valley of the Aa. In this sandstone there is a thin bed of lignite; and the lignites of Käpfnach, near Horgen on the lake of Zurich, of Hohe-Rhonen, the Rufi, the Paudèze, &c. also lie in the sandstone formation. In these lignites of the molassic age we may still sometimes detect the plants which formed them; thus, in the black lignite of Niederutzweil (canton of St. Gall), Prof. Heer found trunks of trees so well preserved, that the annual rings of growth could be counted; and at Käpfnach fragments of the trunk of a palm are not unfrequent. But in general the alteration in lignite is so great that it appears to be a homogencous shining mass, very like true coal, and it often passes by the name of coal. That lignite was produced, like paper-coal, from beds of peat, appears from the remains of marsh-plants in the marls which spread over the lignite and between its layers. The lake-chalk also is not wanting; it appears as a bed of marl, often of a light colour, which in many places still contains the remains of Mollusca (*Unio*, *Planorbis*, and *Lymnæa*).

True Coal belongs to an infinitely earlier period, and has therefore undergone still greater alterations in its composition. Coal is more compressed than lignite, and the vegetable structure in it is more effaced and unrecognizable; its oxygen and hydrogen have been expelled to a still greater extent; and hence the carbon predominates still more in it, and gives it a higher value as fuel. That form of coal from which oxygen and hydrogen have almost entirely disappeared is distinguished as *anthracite*, which, consequently forms the earliest stages in the long series of the coal-formations. Peat has a chemical composition exactly like that of wood; anthracite differs widely from it; and between these two extremes, peat and anthracite, are found paper-coal, lignite, and true coal.

Differences in these substances depend chiefly upon their age —that is to say, upon the greater or less amount of modification which carboniferous rocks have undergone in the lapse of time; and some influence is due to the very different kinds of plants which originated them, and the different external conditions under which they were produced.

When the paper-coals were formed, the climatal conditions of Switzerland and also its flora were the same as at present; but the climate and flora were very different when the lignite was formed, and still more so in the Coal period. Carbon, therefore, was deposited in the earth at that time by quite different species of plants, and under different external conditions. We have already seen that the flora of the coal differs completely from that now existing, but that its general character indicates a moist hot climate. Peat-mosses are not in the process of formation at present in the tropics; but morasses of enormous extent, and of true peat-formation, occur in southern Virginia and North Carolina, countries of the same latitude with Tunis and Algiers.

Lesquereux has given us some interesting information with regard to the peat-mosses of the southern part of the United States, showing that they are produced in exactly the same way as those of Switzerland, and that, notwithstanding the mild winters of the Southern States, the peat attains a thickness of 15 feet. The absence of peat in strictly tropical regions is probably due to the fact that the droughts which cause the complete drying-up of the marshes prevent the formation of peat; but in a constantly hot and moist country, such as was requisite for the coal-flora, the humidity and high temperature would be favourable to the formation of peat. In the production of the peat-mosses of the coal, the *Sigillariæ* (in their *Stigmaria* form) seem to have extended themselves far and wide. They probably spread their long branching roots, closely set with long fibres, over the water and soft mud, forming upon them interlaced masses and floating islands, like those which we still meet with in many lakes of the temperate and warm zones. With these plants were associated the Calamites, whose dwarfish descendants, the Horsetails of our present flora, carpet over the moist ground of forests and beds of deep mud. The Calamites were followed by the *Lepidodendra* and arborescent Ferns, probably as soon as a firmer soil had been established.

This order of precedence is proved by the fact that in the coal-deposits, both of Europe and America, the roots of the *Sigillariæ* (the *Stigmariæ*) always lie in the lower seam of the coal, and frequently compose nearly the whole of that stratum.

In the lakes and pools of the Coal period, *Stigmariæ* were thus widespread like the bog-mosses (or *Sphagna*) of the present day.

But as the *Stigmariæ* were much larger plants, and their roots could spread over a wide surface, they must have produced a far more considerable amount of carbon. As formers of peat and coal they no doubt took the first place; and no plant of a later period has possessed this property in so high a degree. Hence, in the coal epoch, the greater part of the carbon that the plants found in the air in the form of carbonic acid was deposited in the earth; and its quantity was so great that the present atmosphere probably contains scarcely one tenth as much carbon as was deposited in the coal-measures. The circumstance of the air containing more carbonic acid than at present* was very favourable to the growth of plants, but must have been injurious to animal life. The vegetation of the coal, therefore, purified the air and prepared it for the development of the higher animals; whilst at the same time a material was deposited in the earth which, after the lapse of millions of years, has become the foundation of the material civilization of many nations.

The largest European deposits of coal are in England, where they are known to occupy a space of more than 200 square miles, and have been calculated to suffice, at the present rate of consumption, for more than a thousand years to come. The Continent is not so rich in coal; but Belgium, Rhenish Prussia (the district of Saarbrück), Westphalia, Silesia, Saxony, Bohemia, and St. Etienne, near Lyons†, possess large deposits of coal, which will suffice for the needs of several thousand years. North America is richer in coal than Europe; its coal-fields are estimated to extend over 125,000 English square miles.

Unfortunately, in the distribution of this most important natural treasure, only a small share has fallen to the lot of Switzerland. The anthracites of the Valais undoubtedly belong to the Carboniferous period, for they were produced by the same species of plants; but they form a very poor compensation for the abundance of coal which is possessed by other lands. It is certain that at the Carboniferous period the group of the Swiss central Alps was in existence, and that the land was then clothed with plants. The rocks containing the remains of these plants, however, have been altered in their site by the grand convulsions which have changed the aspect of Switzerland, and have become a part of the mountains of that country. In more than one place rocks of the carboniferous series have been inserted between more recent rock masses* in such a manner as to lead some celebrated geologists to assign to Swiss carboniferous rocks an origin which does not properly belong to them.

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* The proportion of carbonic acid in the atmosphere of the earth is from 0·0004 to 0·0006; but G. Bischof estimates that in the coal period this proportion would have been 0·06.

† Switzerland derives its coal chiefly from the basins of Saarbrück and St. Etienne, and a smaller quantity from the Vosges (Bonchamp), localities in which the coal produces much ash, and contains a great amount of sulphur. Coal also comes to Switzerland from Westphalia (the Ruhr district). The increase in the consumption of late years may be seen from the following

The Swiss mountain-convulsions occurred at relatively recent periods; for vast as are the deposits of the Carboniferous formation, they were evidently produced in a tranquil period. It is only in a quiet state that vegetables could have absorbed and assimilated such an enormous mass of carbon and have deposited it in layers in the ground.

We do not possess any certain means of appreciating the duration of the period of time for the Carboniferous formation. From calculations which have been made upon the annual growth of wood, an acre of forest would produce yearly 1000 kilogrammes of carbon, which, if spread over the whole surface, would form a

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Table of the annual quantities of coal imported, principally into Geneva and Basle :—

	GENEVA. cwt.	BASLE. cwt.	TOTALS. cwt.
1850	70,080	145,350	215,430
1852	87,675	237,435	325,110
1854	110,350	220,975	331,325
1856	148,050	409,830	557,880
1858	388,470	702,480	1,090,950
1860	750,000	1,520,310	2,270,970
1861	......	......	3,208,035
1863	......	......	3,544,650
1865	......	......	5,261,130
1866	......	......	5,200,740
1867	......	......	5,083,170

* Professor Favre has thoroughly gone into this problem, and, it may be hoped, has solved it. See his Geological Researches into the vicinity of Mont Blanc in Savoy, Piedmont, and Switzerland, iii. pp. 337, &c.

very thin layer. The increase in peat-mosses is more rapid; but the data are so variable that it is difficult to estimate it exactly; and we can only say that, under moderately favourable circumstances, 1 foot of peat may be produced in a century, or 1·44 line of the French foot in a year, which gives 1500 kilogrammes of carbon to the acre. In the form of coal this would form a layer of 0·33 line, or about one third of a line. To produce a bed of coal 44 feet in thickness, such as occurs in England, a period of nearly 20,000 years would therefore be necessary. If we take twice the increase, or 3 lines annually, 10,000 years would be required, or with four times the increase, only 5000 years.

These calculations are founded upon the present system of vegetable growth; but in the coal period circumstances were probably far more favourable to the formation of peat, and therefore its increase would be much more rapid than in our existing peat-mosses. It must also be borne in mind that the beds of coal, thick as they are, constitute only a small part of the formations comprised in the Carboniferous period; and the time occupied in the deposition of the rock masses (sandstones, clays, and limestones) which surround the coal-beds must have been much longer than that of the coal itself. The thickness of these accompanying rocks has been estimated in many places at 3000 feet; and in the Swiss Alps the strata belonging to the anthracite period are in places 6000 and even 7000 feet thick. It is manifest that the formation of such vast masses of rocks must have occupied an incalculable number of years.

Many thousands of years must have elapsed in a time of quiet development during the Carboniferous period. That epoch was followed by great revolutions, in which the form of the earth's surface became in places materially altered. In the organic world, however, the changes were less profound; for although the flora of the Carboniferous period was in great part destroyed, the plants which have been preserved from the Permian epoch possess a real analogy with the plants of the Carboniferous epoch, and the new genera which made their first appearance present the same general characters as their predecessors.

In Switzerland no fossil remains of the Permian period have been preserved, although some of the Swiss rock masses probably belong to this epoch. Thus it is likely that the Sernifite*, a red sandstone, known in Switzerland as "rother Ackerstein," and containing fragments of quartz, gneiss, clay-slate, porphyry, &c., was formed at this epoch. It constitutes a special portion of the Swiss Alps, between the valley of the Sernft, the lake of Wallenstadt, and the valley of Setz, and forms the rock of some of the highest mountains in that part of Switzerland, such as the Kärpf (8613 feet above the sea) and the Hausstock (9715 feet). It also appears at Davos, as well as in some districts of Western Switzerland.

The Sernifite is very like a red rock which occurs in Saxony and Thuringia, and is there known as "Rothliegendes" (the red lier, from its colour), and "Todtliegendes" (the dead lier, from the copper having died out). In those countries it is closely associated with a dark-coloured shaly sandstone containing copper (the Kupferschiefer) and with strata of marl and limestone (the Zechstein), the whole group constituting the formation which has been named the Permian (from the province of Perm in Russia) or the Dyas.

The Sernf rock contains an argentiferous copper-ore. As early as 1680 this ore was worked on the Mürtschenalp, in the canton of Glarus, and to a greater extent from 1854 to 1861, when the mines were again abandoned, as the amount of ore obtained did not cover the expense of working in an inhospitable alpine region. Most of the copper worked in mines is deposited in the Permian formation, both in Europe (as, for instance, in Eastern Russia, Saxony, and Thuringia) and in North Ameria, on which continent the neighbourhood of Lake Superior is distinguished by the largest known masses of copper. It would appear that copper was first worked in the island of Cyprus (whence is derived the Greek name of the metal, *Kupros*). Among the Greeks copper was consecrated to Venus, the national goddess of Cyprus.

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* Hitherto no fossils have been found in this rock, which renders it difficult to determine its age. It has its greatest development in the valley of the Sernft, formerly known as the Sernif, which has led Prof. Heer to give the name of Sernifite to this kind of rock. The Italian name Verrucano (from Verruca, a castle in Tuscany), which has been employed to designate the Swiss rock, belongs to some rocks of the carboniferous series.

During the Permian epoch conditions very favourable to the deposition of copper must have prevailed, either by vapours laden with copper ascending from the interior of the earth and depositing that important metal in the rocks, or by salts of copper being dissolved in water and precipitated and accumulated in the course of centuries; the question, however, why it was precisely at the Permian period that the copper was deposited in the earth is not solved by the theory of aqueous solution of salts of copper.

The great Carboniferous period terminated with the formation of the Permian rocks. At that time, in North Germany, vast and numerous masses of porphyry were forced up from the interior of the earth and covered a great extent of country. Preparation was made for a new order of things, which we will describe in the next chapter.

CHAPTER II.

THE SALIFEROUS FORMATION OF SWITZERLAND.

LITTLE more than a century has elapsed since the employment of steam gave to coal its important position as the grand support of industry and commerce; but for thousands of years salt has been regarded as one of the necessaries of life, and as a highly valuable mineral.

In the state of rock-salt it forms complete deposits, and is found in the interior of mountains belonging to the primæval world.

Salt mountains many miles in extent occur in Transylvania, with precipitous walls of pure rock-salt often 100 feet in height. At Cardona, on the southern slope of the Pyrenees, there is a deposit of rock-salt, the exposed portion of which, from 80 to 100 metres in height, is so torn and furrowed by the action of rain-water, that, if a person were to look at its pyramids, projections, points, and miry places, he might suppose it to resemble a glacier; and so great is the collection of salt in this locality, that it is regarded as inexhaustible, although it has been worked like a quarry for centuries. (It is mentioned as early as A.D. 1103.) Still larger masses of salt exist in the long salt chains to the south and north of the Himalayas; at Kallabaugh the road is cut for a long distance through rocks of salt 100 feet in height; and even these are surpassed by the salt rocks surrounding the lake of Titicaca, which measures 218 miles in length, and is situated in the Peruvian Andes.

As salt dissolves readily in water, all lakes situated near salt rocks have salt water; and the sea itself is salt, although rivers bring to it only fresh water. Sea-salt may be produced by the combination of its two elements, sodium and chlorine, which have been conveyed into the sea; or it may have been dissolved by the sea from salt rocks. Thus the sea would be itself a salt-producer, and it also dissolves the salt contained in saliferous rocks covered by it; and a uniform diffusion of salt takes place in all seas from the constant agitation of the water by currents. The water of the Atlantic Ocean contains 3·52 per cent. of solid salts; and 1000 pounds of sea-water would contain about 27 pounds of common salt (chloride of sodium)*.

Wherever sea-water is evaporated the marine salt is deposited, and in many coast-regions salt is thus obtained. Sir Charles Lyell describes a large depression (one fourth the size of Ireland) near the mouth of the river Indus, which is sometimes covered by sea-water and sometimes left dry. In the latter case it is covered in parts with a crust of salt an inch thick. By continual deposition of salt in this manner during a very gradual sinking of the district, layer after layer of salt might be produced.

Whether all rock-salt originated by deposits and gradual depressions, or whether a portion of the salt may have been produced in some other way in the interior of the earth, cannot at present be decided; but the salt-deposits of Switzerland were produced by evaporation. The most important are on the left bank of the Rhine, extending from Ryburg (near Rheinfelden) to Basle. Borings executed at Schweizerhall (between Basle and Augst) in 1836 revealed a deposit of rock-salt about 30 feet thick, at a depth of 420 feet; at Rheinfelden the salt-deposit has probably a thickness of about 60 feet.

That these salt-deposits owe their origin to a dried-up sea is proved by the numerous marine bivalve shells which have been found in many places in the limestone bordering upon the deposit of salt. From the abundance of these shells the rock has received the name of "Muschelkalk" (or shell-limestone). With the salt different deposits are found, such as gypsum and anhydrite (anhydrous sulphate of lime), which are surrounded by shell-limestone and marl. In Switzerland these conditions could be ascertained only by borings; but in the mining district of Salzburg, and at Berchtesgaden in Bavaria, numerous horizontal workings penetrate into the interior of the mountain; and by analogy we may thus determine the character of the Swiss saline strata.

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* Besides common salt (chloride of sodium) sea-water contains sulphate of magnesia, sulphate of lime, chloride of potassium, and chloride of magnesium.

Passing, at Berchtesgaden, through the overlying dolomite, we reach the lower bed, composed of marl, mixed with salt. This marl comprises fragments of blackish-brown clay, penetrated by salt, sometimes scattered in veins through the dark masses, sometimes forming compact whitish or red shining layers. Here and there the galleries widen into great chambers and caverns, the middle of which is sometimes occupied by a small pool; and their walls and roofs sparkle with myriads of salt crystals. These chambers, which constitute the wonders of the salt-mines, are the result of the mode of obtaining the salt. When the galleries have been driven through the lower beds, so as to reach the salt, water is admitted, which dissolves the salt and the soft masses of clay; the walls separating the neighbouring galleries fall in, and thus the large chambers are produced. When the water is sufficiently saturated with salt it is drawn off and boiled, and the salt is obtained from it by evaporation.

A different process is adopted in the Swiss salt-works. A boring is driven down into the deposit of salt, and water is conducted through it, so as to dissolve the salt; the water is then pumped out and evaporated. In this way, according to M. Guntert, director of the salt-works at Rheinfelden, about 590,000 cwt. of salt are annually produced from the Swiss salt-works—namely, 230,000 from Schweizerhall, 70,000 from Augst, 145,000 from Rheinfelden, and 145,000 from Ryburg. The salt-works of Bex, in the Canton de Vaud, at present furnish only 25,000 cwt. The salt here, surrounded by gypsum and anhydrite, forms veins and nests in the limestone rock. The saline rocks (which contain, on an average, 30 lbs. of salt to the cubic foot of mineral) were discovered in 1554; for 150 years foreigners paid a rent to work these salt rocks, as a fief of the state of Berne; and afterwards the government took charge of the establishment. In 1798 the salt-works became the property of the Canton de Vaud. In 1823 their produce had fallen to 13,400 cwt.; but by the admirable management of their director, Johann von Charpentier, the discovery of new deposits of salt multiplied threefold the produce of the mines. The two most important workings are the "Mine du Fondement" and the "Mine de Bouillet," the entrances to which are situated in the romantic valley of La Gryonne. The former has many galleries at different levels; the latter a straight gallery of 6600 feet in length, in which are reservoirs for collecting the water impregnated with the rock-salt. Mines are blasted in the salt rock, and the fragments are put into large reservoirs, where the salt is dissolved by fresh water. The strong brine (containing 25–26 per cent. of salt) is then boiled down in the pans situated at the Bevieux. Some years ago Bex produced 146,000 cwt. of salt; but the production has now diminished by about one half, and the boiling-houses which formerly existed at Devens have been abandoned. At Bex, as at Rheinfelden, salt water is employed for the benefit of health; and bathing-establishments have been formed in both localities.

These Swiss salt-works furnish the greater part of the salt consumed in Switzerland. About 150,000 cwt., however, are imported annually, which brings the ordinary annual consumption to 700,000 cwt.* In German Switzerland the additional quantity required is obtained from Wilhelmshall, near Villingen in Württemberg, and from the salt-works of Baden.

As we have already mentioned, the German saline deposits are conformable with those of Northern Switzerland; so that they were probably formed at the same time and in the same manner. In Württemberg the deposits of rock-salt, which are 30–50 feet thick, agree perfectly in their chemical constitution with the salt of sea-water. That there were many oscillations of the ground during the rock-salt-formation is shown by the existence of layers of Muschelkalk and clay here and there on the beds of salt; and as the clay and limestone must have been deposited under water, their occurrence proves that a depression of the ground took place after the deposition of the salt.

The period of the formation of these salt-deposits is determined by the remains of animals (and especially the shells) which occur in the Muschelkalk; and these remains give us a glimpse of the animal inhabitants of the shallow sea which, in that

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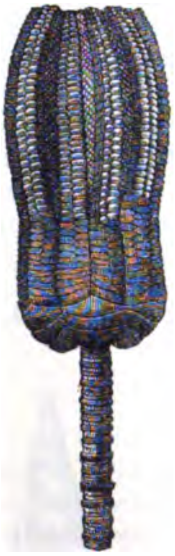
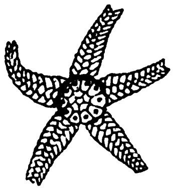
* About 70,000 cwt. are exported from Switzerland every year.

Fig. 18.



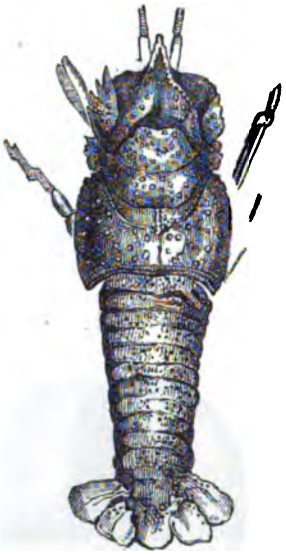
Encrinus liliiformis.

Fig. 19.



Aspidura scutellata.

Fig. 20.



Pemphix Sueurii.
Half nat. size.

distant age of the world, covered Switzerland. Among the abundance of forms we observe a long-tailed crustacean (*Pemphix Sueurrii,* fig. 20), which has been found in many places (at Augst, Rheinfelden, Schwaderloch, &c.). It is characterized by its tuberculated carapace, divided by deep transverse furrows and lengthened out in front into a beak. As the lobsters live in the neighbourhood of the shore and among the clefts of rocks, or at any rate never at great depths, this species indicates a shallow coast-line, as does also the little delicate starfish (*Aspidura scutellata,* Blum., fig. 19) and the singular encrinite or stone lily (*Encrinus liliiformis,* fig. 18). The encrinite belongs, like the starfish, to the class of Echinodermata, but lived attached to rocks by means of a long, ringed stem nearly as thick as one's finger. (In the quarries of Felsenau on the Aar, stems 6 feet long have been found.) At the summit of this stem the body of the animal is seated, like a calix on its stalk; its arms (usually, at most, twenty in number, placed together in pairs) were folded together and gave the appearance of a sort of flower-bud. The upper parts of the bodies of these animals are not so often met with as the stems, which occur in abundance. At Müllingen, on the banks of the Reuss, the rocks are full of the débris of this encrinite.

Whilst these animals are quite foreign to our existing fauna, the Mollusca of the same age present us with numerous species which approach much more closely to those of our present seas, and some belong to living genera. In Argovia, M. Kas. Mösch has enumerated 57 of these species. The richest deposits are at Eiken near Schwaderloch, and near Augst, Rheinfelden, Laufenburg, Etzgen, Felsenau, Strychen, and Waldshut. Near the mill at Etzgen, and near Schwaderloch, according to M. Mösch, the rocks consist almost entirely of shells, indicating a locality once peopled by an innumerable colony of these animals. Among the different species we may notice especially the *Lima lineata* (fig. 21), characterized by its two large, horn-like, and deeply striated valves, the smooth flat comb *Pecten lævigatus* (fig. 22), and a widely distributed *Avicula* (*A. socialis*, fig. 23). Univalve Mollusca are not uncommon; and these also belong chiefly

Fig. 21.

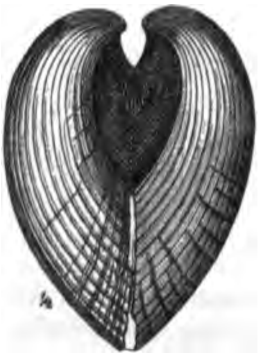


Fig. 22.

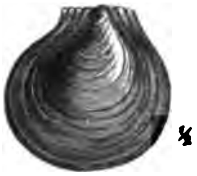
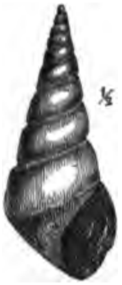


Fig. 24.



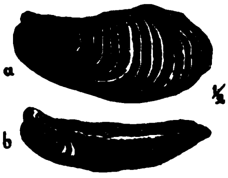


Fig. 23.

Fig. 21. *Lima lineata*, from Basle (Augst), half nat. size.
Fig. 22. *Pecten lævigatus*.
Fig. 23. *Avicula socialis*: *a*, from the side; *b*, from above.
Fig. 24. *Turbonilla scalata*.

to living genera: such are the turreted *Turbonilla* (fig. 24) and the species of *Natica* and *Trochus*, also a fine *Nautilus* (*N. bidorsatus*, fig. 26) of which very large specimens (a foot in diameter) are sometimes found.

In *Ceratites nodosus* (fig. 25) we have the first representative of the family of the Ammonites, which does not extend down to the present day. The Ammonites and *Nautili* belong to the group of Cephalopoda, and occupy the highest position among the Mollusca. They are characterized by the peculiar structure of their shell, which is divided into a number of chambers, separated by septa. The animal dwells in the foremost chamber, and communicates with the other empty ones by a small opening in its septum; through this aperture passes a fleshy cord, the siphon, which reaches the first chamber, to which it is attached. In the Ammonites the septa are always traversed by the siphon near the back; and their margins, where they unite with the shell, form curved and zigzagged lines (called lobes); whilst in the *Nautili* the position of the siphon varies and the margins of the septa are straight or gently curved. The *Nautili* now occur only in the Indian seas; they make their appearance in the Carboniferous rocks long before the true Ammonites; and even in the Ammonitidæ of the Swiss Trias the margins of the septa are by no means so complicated as in the case of the true Ammonites, but form only semicircular undivided lobes (see fig. 25).

Fig. 25.

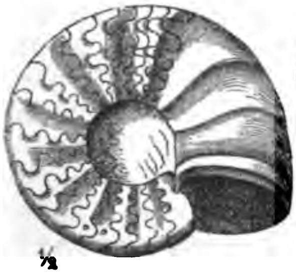


Fig. 26 *a*.

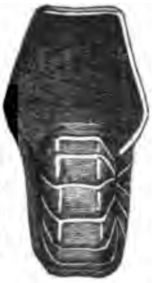


Fig. 26 *b*.

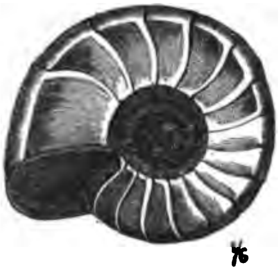


Fig. 25. *Ceratites nodosus.*
Fig. 26. *Nautilus bidorsatus*: *a*, from the side; *b*, from the front.

These numerous Mollusca probably served as food for Fishes and Reptiles, large species of which roved through the Triassic sea. The Reptiles make their appearance in two very singular forms, such as only the early days of the earth can show us, namely the Fish Lizards (*Ichthyosaurus*) and the Sea-Lizards (*Nothosaurus*). They had four swimming-feet, and were therefore organized solely for an aquatic life. *Nothosaurus mirabilis*, the remains of which were discovered at Schwaderloch, had a long snake-like neck and a small slender head; and its mouth was armed with a row of sharp teeth, besides two large canine teeth and five cutting-teeth. The *Ichthyosaurus*, on the contrary, had a short neck, and is rendered extremely remarkable by its long mouth, tapering so as almost to form a beak, and by its enormous eye, embraced by a ring resembling horn. Its great mouth was furnished with numerous teeth like those of crocodiles; and the animal was thus specially fitted for seizing and tearing its prey, whilst its large eye must have facilitated vision in the obscurity of the waters. In general form and in its fin-like limbs the *Ichthyosaurus* resembled the Dolphins; but its head was constructed more like that of the Gavial (*Rhamphostoma*). Fragments of skin, teeth, and bones of one species (*Ichthyosaurus atavus*, Quenst.) have been discovered by M. K. Mösch at Lauffenburg, Etzgen, and Schwaderloch.

Such are the animals which characterize the Saliferous or Triassic period, following immediately after the Permian division of the Carboniferous formations. The epoch may be called the Salt period, as at that time most of the rock-salt of Europe was deposited; but it must not be forgotton that the sea has given rise to deposits of salt at other periods, and that similar deposits are still formed.

The name of TRIAS is preferred by most geologists for this series of rocks, as the formation subdivides itself into three sections.

In Switzerland the central part of the series, the Muschelkalk, is from 600 to 700 feet thick; and beneath it there is a brownish or ochreous-red sandstone, which has received the name of "Bunter Sandstone." It occurs on the northern slopes of the Jura, at Rheinfelden, Seckingen, and Waldshut, and furnishes an excellent building-stone. The cathedral and other public buildings of Basle are constructed of this stone, obtained from the quarries between Augst and Rheinfelden. At Waldshut it contains much quartz, and furnishes valuable mill-stones, which are carried to great distances. Above the Muschelkalk, which crops out at many places along the Jura, when the Bunter Sandstone does not appear, we find soft and hard marls, and often green sandstones, forming the uppermost member of the Trias, and which have received the name of "Keuper"*. In the canton of Basle the Keuper is about 400 feet thick. Near Hämiken there is in it a large quarry, which furnishes a hard and valuable building-stone. Here and there this stone encloses the remains of plants, which give us some notion of the flora of that epoch; but the plants are better preserved in the Keuper marls of Asp near Pratteln, of the Moderhalde below the Prattelerhorn, and of Neuen Welt (in the commune of Mönchenstein), only about two miles from St. Jacob. The rocks which contain the greatest abundance of plants are situated near the Rütihard (in the Neuen Welt), where the marls appear in the banks of the Birs, and are traversed here and there by thin streaks of coal and filled with blackish-brown plant-remains. The leaves are so well preserved that many of them retain their flexibility, and can be separated from the stone. When placed under the microscope their cellular structure can be recognized, and even the localities of the small fissures can be seen, through which the plants received air. These plants, therefore, may give us important information as to the flora of Switzerland at the Keuper epoch; and for this purpose we have to consider them.

Prof. Heer has hitherto obtained 25 species of plants from the Keuper of the canton of Basle. They are all land-plants, showing that there was dry land in this region at the time of the Keuper, whilst during the formation of the Muschelkalk the land was below the level of the sea. How large a portion of land was dry cannot be ascertained positively; but we know that at the time of the Keuper the whole district of the Black Forest as far as the neighbourhood of Baden-Baden, and also the mountains of the Vosges, were dry land. We have mountains of primæval granite and greywacke, and in many places the remains of the land-flora of the Carboniferous and Bunter Sandstone formations, both in the Vosges and in the Black Forest. The central granitic land was overlaid first with the Bunter Sandstone and the Muschelkalk, and then with the Keuper; so that the Keuper country of the Birs evidently forms a continuation of this continent; and as Prof. Heer has received Keuper plants from Passwang and the Stafelegg, it must have extended to those places. That it stretched northwards over a considerable part of Württemberg and Bavaria is proved by the plants found there in various places, the majority of which agree specifically with those of Basle, and show that the whole of this district had a similar flora. Of the 25 Swiss species 16 have been observed elsewhere in the Keuper; and 11 of the Swiss species have been met with in Württemberg.

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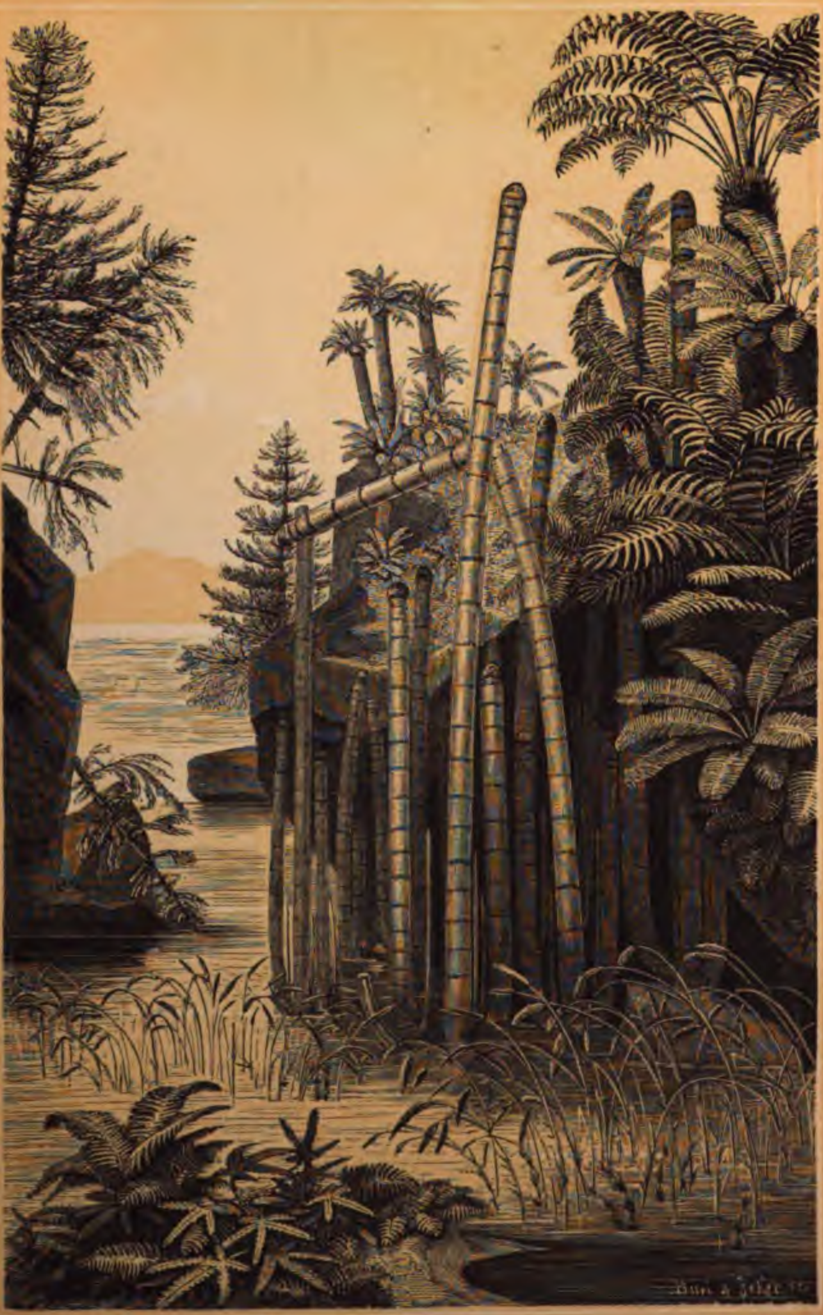
* In Coburg "Keuper" or "Köper" is the name given to a variegated checked stuff; and from this, no doubt, a variegated rock belonging to the Trias which occurs there has received the same name. Leopold von Buch transferred the local denomination to the whole formation.

Whilst the Permian flora is still carboniferous in its character, the Keuper flora is quite different. All the species are changed; and those very forms, such as the *Lepidodendra*, *Asterophyllitæ*, and *Sigillariæ*, which were of most importance in the time of the coal have now disappeared. The flowerless plants (the vascular Cryptogamia) form two thirds of the whole number; and many genera (such as *Neuropteris*, *Sphenopteris*, and *Pecopteris*) remain the same; but while the Lycopodiaceæ have lost all their importance, Horsetails (Equisetaceæ) of large size appear, and the Cycads and gymnospermous flowering plants are represented by many remarkable and peculiar species.

An approximation to the landscape of the neighbourhood of Basle, in the Keuper epoch, is given in the accompanying Plate. In the foreground the palmate fronds of the *Clathropteris* spread side by side with the feathery fronds of the *Pecopteris Meriani*; from the water rise young whorl-leaved *Schizoneuræ* and the slender stems of the *Æthophylla*, with their fruits collected into dense spikes; but these are insignificant compared with the gigantic Horsetails (*Equiseta*), which spring like columns from the shallow water. On the rock to the right we see first a young *Pterophyllum Jægeri*, surrounded by the finely divided fronds of *Pecopteris augusta*; higher up is a specimen of *Danæopsis maran-*


Buri & Jeker lith.

BASLE DURING THE KEUPER PERIOD

tacea, followed by *Pterophylla,* over which a large *Danæopsis* spreads its beautiful feathery fronds. The distant view comprises the *Voltzia,* with its needle-shaped leaves.

Of the plants composing this Keuper flora, the most abundant and important are the gigantic Horsetails (*Equisetum arenaceum,* Jæg.) and the species of *Pterophyllum,* which occur not only in the hard sandstone of Hämiken and in the clay rocks of the coals of the Rütihard, but also on the Passwang (in the Canton of Soleure) and in the German Keuper country.

Of the great *Equisetum,* or Horsetail, the fragments represented in fig. 27 give us a correct idea. It formed cylindrical stems as thick as a man's arm (3–5 inches in diameter), which may have attained a height of 20 feet, as fragments of 12 feet in length have been found. Like their dwarfish relations of the present day, these giant *Equiseta* were jointed and furnished at the joints with a closely fitting, deeply striated sheath, cleft above into numerous teeth (often more than 100), terminating in fine long points. (Fig. 27, *f,* shows a portion of one of these sheaths of the natural size.) On the lower part of the stem these teeth were short, broad, and obtuse (fig. 27, *e*). The stems are quite blunt at both ends (fig. 27, *d,* the apex of a stem, and *h,* the base, ⅙ natural size), where they have short joints; in the middle of the stem the joints attain a considerable length, (6 inches). From the lower joints spring single branches (fig. 27, *g,* a branch of the natural size), which ascend and surround the branchless upper part of the main stem; and thus these slender, cylindrical*, and finely striated columns were surrounded by isolated thin twigs (as shown by fig. 27, *a, b,* restored fragments, ⅙ the natural size). From a fragment of a fruit discovered in the Rütihard (fig. 27, *c*), we learn that these plants had fruits like those of the living *Equiseta,* only larger. In it we see many pentagonal and hexagonal scales united into a cone, and, no doubt, enclosing numerous minute spores. At the base the stem was probably buried in the mud, and it formed wide-spreading rhizomes, attached to which, just as in our

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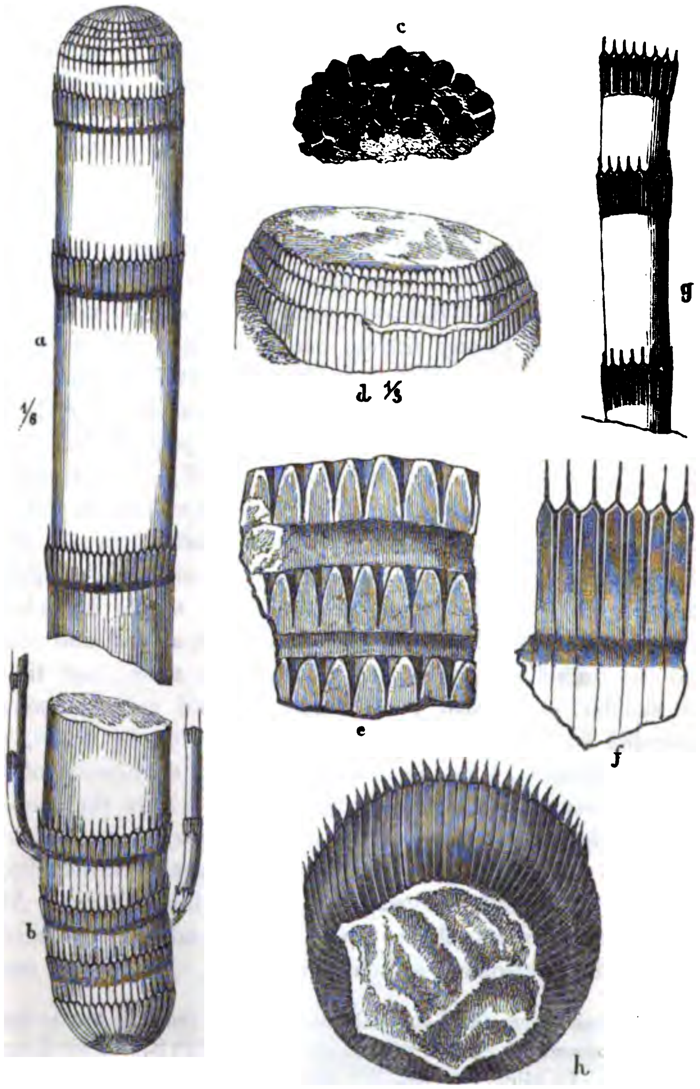
* In the species from the Keuper the stems are cylindrical; but in the *Equisetum columnare,* Br., which is often confounded with it, they swell out at the joints. In other respects they agree, so that it is still doubtful whether they are specifically distinct.

Equiseta, there were tubers of the size of an egg, serving, doubtless, as reservoirs of nutriment. Frequently the smooth outer bark and the sheaths have fallen off, and only the finely and

Fig. 27.

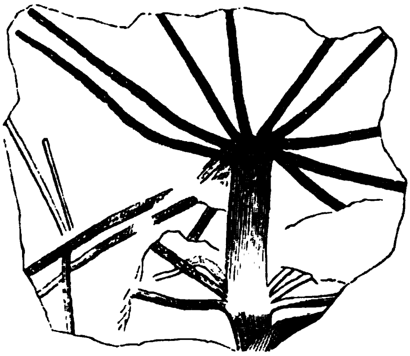


Equisetum arenaceum, Jæg., from the canton of Basle.

sharply striated inner portion of the stem has been preserved. Such specimens were formerly described under the name of *Calamites arenaceus*.

Besides this, we find in the Keuper of Basle a smaller species of *Equisetum* (*E. Münsteri*, Sternb.), with sharply toothed sheaths and small globular cones, and also a species of the allied genus *Schizoneura* (*S. Meriani*, Br., fig. 28). In the latter there is at each joint a whorl of rigid linear leaves.

Fig. 28.



Schizoneura Meriani, Br., from Moderhalde, near Prattelen.

These plants probably grew in the marshes, and perhaps even in the water, like the Swiss Marsh Horsetails. *Æthophyllum speciosum*, Sch., seems to have been associated with them; it was probably most nearly allied to the Reed-maces (*Typha*) of the present day. The leaves and fruits of *Æthophyllum* are abundant in the Bunter Sandstone of Alsace and of Rigoledo on the lake of Como; in the Canton of Basle (Rütihard) only the leaves have been found, and their determination is still doubtful.

The predominant trees of the Swiss Keuper forest were the Zamians, of the genus *Pterophyllum*. Europe at present possesses no trees which can be compared with these; but in South Africa we find the Cycadaceous genera *Zamia* and *Dion*, which must be regarded as their nearest relatives. These are trees whose stem is at first spherical, but afterwards cylindrical, closely embraced by woody scales, and having at its apex a crown of large pinnate leaves. In aspect they resemble the Palms, from which, however, they differ in the rigid leathery texture of their leaves and in the structure of their fruits. In the latter respect and in their naked seeds they approach the Pines and Firs, and form with these the subclass Gymnospermia. The *Pterophylla* of the Keuper country had rigid pinnate leaves, like those of the African *Zamiæ*, the flat pinnæ of which are traversed by numerous longitudinal veins; but the pinnæ are attached by their whole breadth to the leaf-stalk, which is channelled in the middle. The male flowers formed a dense spike (Pl. III. fig. 5, from Mönchenstein, in the Canton of Basle); and the fruits formed a cone, consisting of hexagonal, shield-like bracts (Pl. III. fig. 4, from Hämiken). Four species of *Pterophyllum* have been discovered in the Keuper of the Canton of Basle. The most abundant is *Pterophyllum longifolium*, Br. (Pl. III. fig. 6, two-thirds natural size), the leaves of which were 1 to 2 feet in length and 3 to 4 inches broad, the pinnæ being a little narrowed towards the base, and somewhat more distant from each other towards the apex of the leaf; whilst in *P. Jægeri*, which occurs abundantly in Switzerland, as well as in the Keuper Sandstone of Stuttgart, the pinnæ, which are 2½ inches in length, are of the same width, and are placed very close together throughout (Pl. III. fig. 2, half nat. size). Very nearly allied to this is *P. brevipenne*, Kurr. (Pl. III. fig. 1, half nat. size), in which, however, the pinnæ are much shorter; whilst *P. Meriani*, Br. (Pl. III. fig. 3), is remarkable for the elegant form of its little pinnæ.

With these Cycads of the Swiss Keuper forest there were associated two Conifers, a *Voltzia* and a *Widdringtonites* (*W. keuperianus*, Heer). Of the *Voltzia*, only a few scales of the cone have been found in Switzerland (fig. 29); but the Bunter Sandstone of Alsace has furnished numerous leafy twigs, flower-spikes, and cones, figures of which have been given by Professor Schimper, so that we have a complete idea of this tree, which, at the period now under consideration, was widely distributed in all Triassic countries. In its general appearance, and its dentated scales, it resembles the Japanese *Cryptomeria*, now frequently seen in our plantations, which is one of the largest and handsomest Conifers of Japan. Like it, the *Voltziæ* had thin twigs densely covered with leaves (fig. 30, *a*); but the male spikes (fig. 30, *b*) and cones (fig. 30, *c*) were much larger.

At present we know the *Widdringtonites* very imperfectly, as only a few of its twigs have been obtained (fig. 31, *a*, *b*). These

Fig. 30.

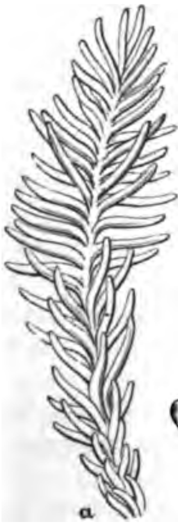


Fig. 30.

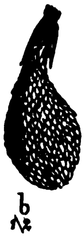


Fig. 30.

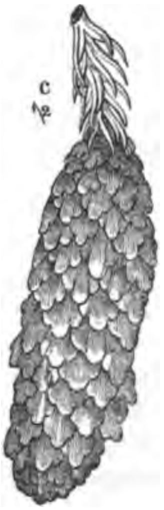
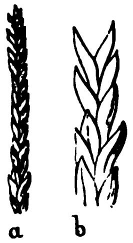


Fig. 31.



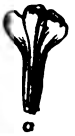


Fig. 29.

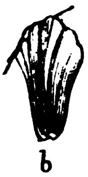


Fig. 29.

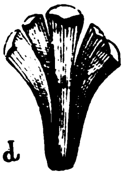


Fig. 30.

Fig. 29. Scales of the cone of *Voltzia*: *a*, from Prattelen; *b*, from Rütihard.

Fig. 30. *Voltzia heterophylla*, Sch. (after Schimper): *a*, branch; *b*, male-flower catkin, half nat. size; *c*, cone, half nat. size; *d*, scale of the cone, nat. size.

Fig. 31. *Widdringtonites keuperianus*, Heer, from Rütihard: *b*, portion of a twig, enlarged.

are covered with small scale-like, alternate, pointed leaves; and the species probably resembled the Savin (*Juniperus Sabina*) in its mode of growth.

The Ferns, which still constitute the most abundant family, probably grew in the shadow of the forest; they chiefly belong to the same genera as those of the Carboniferous period, but to different species. We have a fine-leaved *Sphenopteris* (*S. Ræssertiana*, Sternb., Pl. II. fig. 4), a *Neuropteris* with very distinct veins (*N. Rütimeyeri*, Heer, Pl. II. fig. 6), and four species of *Pecopteris*. The most abundant species is *Pecopteris Meriani*, Br., beautifully preserved fronds of which, partly bearing their fruit (Pl. II. fig. 3), have been found at Prattelen. Its fronds were bipinnate, with the pinnules either free (Pl. II. fig. 3) or united (fig. 2) at the base; they had numerous forked veins springing from a leaf-stalk. The clusters of cases containing spores (sori) were placed in two rows on each pinnule; and each of them consisted of four comparatively large capsules (Pl. II. fig. 3, *b*, magnified). Judging from their mode of fructification, the species belongs to the Gleicheniaceæ. Allied to this is *Pecopteris augusta*, Heer (Pl. II. fig. 8), with long, narrow pinnæ, notched at their edges, and traversed by delicate veins. The *Pecopteris triasica*, Heer (Pl. II. fig. 7), from Hämiken exhibits much larger and more sharply cut lobes; in this species, probably, numerous pinnæ were attached to a common frond-stalk, as in the allied English species, *P. whitbiensis*, Br. On the other hand, *Pecopteris gracilis*, Heer (Pl. II. fig. 1), must have had very delicate and finely formed fronds; it reminds us of the forms of the tropical Gleicheniaceæ.

These genera are accompanied by arborescent Ferns. Two representatives of the *Tæniopteris* are *Danæopsis marantacea*, Sternb., and *Tæniopteris Haidingeri*, Ett., which occur in the Canton of Basle and in the German Keuper. The former had pinnate fronds 2 or 3 feet long, the pinnæ of which were about 6 inches long and 2 inches broad, and were traversed by forked lateral veins. Along these veins the fruits stand in rows, but so numerous and so closely packed together, that they cover nearly the whole lower surface of the frond, as shown by the well-preserved specimens from Rütihard (Pl. II. fig. 5, a fragment with fruit; figs. 6, 7, magnified). Whilst the *Danæopsis* and the *Tæniopteris* had on the summit of the stem a crown of large, stiff, pinnate leaves, the *Camptopteris quercifolia*, Sternberg, spread out its leaves divided into lobes to about the middle and arranged with radiating and reticulated veins. Such palmate leaves occur at present only among tropical ferns, and the *Danæopsis marantacea* can only be compared with the Danæaceæ of Brazil, which live near the coast, and have an erect trunk adorned by a crown of leaves cut into lateral segments, the fertile pinnæ of which are densely covered with fruits.

Two other genera, peculiar to the Keuper, probably belong to the Ferns; but their position in the system is still uncertain: these are *Clathrophyllum* and *Sclerophyllina*. The former (*C.*

Meriani, Heer, from Rütihard) had palmate leaves like *Camptopteris* or *Cheiropteris*, but with very narrow, entire lobes, traversed by numerous fine longitudinal veins (Pl. II. fig. 10), which were united by transverse veins in such a manner as to produce a delicate latticework (fig. 10, *b*). *Sclerophyllina furcata*, Heer (Pl. II. fig. 9), possessed rigid, narrow leaves, dividing into a fork, and traversed by two striæ.

Vegetation of the character here described form the plants of the Canton of Basle spread over the whole of the Keuper land; we find generally the same species in Wirtemberg, and the north of Bavaria; and even in America (at Richmond, in Virginia, and in North Carolina) we meet with the same genera and even with some of the same species. Such was the aspect of the flora when the Keuper sandstones and marls of Basle were formed; and it was probably the same also when the salt and the Muschelkalk of this region were deposited at the bottom of the sea and in the shallows of the coast. It is true that neither the Muschelkalk nor the salt-deposits contain terrestrial plants, as they were formed in the sea; but the subjacent Bunter Sandstone shows us a flora which has essentially the same character as that of the Keuper, and leaves us no room to doubt that the shores of the salt-sea were clothed with a similar vegetation. As yet, indeed, in Switzerland, only one species of plant has been found in the Bunter Sandstone (*Equisetum Musgeotii*, Br., from Rheinfelden); but more have occurred in Alsace, especially near Sulz. The *Voltziæ* already referred to are there abundant; and the *Equisetum arenaceum* and species of *Æthophyllum* and *Schizoneura* also dwelt there. But with these are associated several peculiar ferns, such as the arborescent *Anomopteris* with its large fronds, two Cycads (*Zamites vogesiacus*, Sch., and *Nilssonia Hogardi*, Sch.), and some Conifers (*Albertia*) which remind us of the Kauri or Dammara gum-trees. Near Sulz the latter seem to have formed, with the *Voltziæ*, the principal part of the forest; four species of them occur—namely, *Albertia latifolia*, *A. speciosa*, *A. elliptica*, and *A. Braunii*. They are nearly allied to the genus *Dammara*, and have the same broad leaves with delicate longitudinal veins; their elongated cones also consist of leathery scales, each of which bears an inverted seed, furnished with a wing-like border. They were probably pine trees like the *Dammaræ,* of which one species (*D. orientalis,* Lamb.) inhabits the Sunda Islands, and another (*Dammara australis,* Salisb.) the north of New Zealand (between 34½° and 37½° S. lat.). The latter is the Kauri pine, the king of the New-Zealand forests, described by Hochstetter as bearing at the summit of a majestic column a crown of branches interlaced so as to form a green cupola, through the interstices of which the light of day twinkles like a collection of golden stars illuminating the forest. The crowns of the Kauri pines rise far above the other forest-trees, and form dark shadows on the slopes of the mountains and in the valleys, enlivened here and there by the light-green fronds of the tree ferns, which grow luxuriantly wherever the water of a spring trickles over the ground.

The forest of *Albertia,* of which the remains are enclosed in the sandstones near Sulz, probably presented a similar appearance. Deciduous trees, as well as all the more highly organized flowering plants, are wanting in the Bunter Sandstone and in the Keuper; in fact, throughout the Triassic period, as well as during that of the Coal, the forests had a very uniform character. Terrestrial animals appear, but they must have been very rare. In the Keuper marls of the Rütihard, Professor Heer has vainly sought for insects; but in the black shales of Vadutz he has found two species of beetles (*Buprestites Pterophylli* and *Curculionites prodromus,* Heer). In the Bunter Sandstone, near Richen, impressions of the scales of a gigantic *Labyrinthodon* and the skeleton of a little Batrachian allied to the Salamanders have been discovered. Near Rheinfelden, in the Bunter Sandstone a species of crocodile (*Sclerosaurus armatus,* Myr.), and the head-shields of a large *Mastodonsaurus* have been found. Professor Heer has discovered in the Keuper of the Schambelen some large bones, probably belonging to an animal of the same class; but the Professor cannot decide whether these creatures lived on the land or in the water. In Wirtemberg, numerous Saurians have been met with in the Keuper; the most abundant species (*Belodon Plieningeri,* Myr.) was very like the gavial of tropical America. The genus *Teratosaurus* includes similar but still larger animals; to this genus probably belong the gigantic bones which Gressly discovered at Liestal, and for which Professor Rütimeyer proposed the name of *Gresslyosaurus ingens*.

The beautiful impressions of plants contained in the Keuper of the Canton of Basle and that of the Passwang and the Staffelegg prove that district to have been a freshwater formation; but further south, at Schambelen, in the Canton of Aargau, was the sea; and in that locality Professor Heer found, in the yellowish grey slaty dolomite, the teeth of a marine fish (*Ceratodus Kaupii*, Ag.), and a quantity of the shells of a small crustacean (*Estheria minuta*, Alb., Pl. III. fig. 11), formerly described as a mollusk of the genus *Posidonomya*. These little crustaceans had a bivalved carapace closely surrounding the softer parts of the animal, and merely allowing the extension of its thin delicate claws, which have only been seen in one specimen. Twenty-two living species of *Estheria* are known; like their nearest relatives, the *Limnadia*, they live in fresh and brackish water. In the upper beds of the Lias and in the clays of *Opalina*, at Schambelen, *Estheriæ* (*E. Bronnii* and *E. opalina*) occur in great quantities associated with marine animals; and it is therefore probable that *Estheria minuta* lived in the shallow parts of the sea and in brackish water. With it Professor Heer finds at Schambelen great quantities of a bivalve shell (*Lucina Romani*, Alb.), the two valves of which are frequently united; and the presence of these animals indicates the neighbourhood of a coast and brackish water.

Above the deposits filled with *Estheria* and *Lucina*, Professor Heer finds a thin stratum containing great masses of *Bactryllium canaliculatum*, Heer (Pl. III. fig. 9, enlarged 10 times). This is a flat rod-like organic substance, traversed by one or two longitudinal furrows. Its nature is still problematical; but, notwithstanding its size, it most likely belongs to the Diatomaceæ. It is hollow within (Pl. III. fig. 9 *a*) and has a thick, solid wall, which generally exhibits an elegant striation on the outside.

The Triassic sea probably washed over the whole lowland of Switzerland, now covered by the molasse; but in the interior of the country its deposits have as yet been discovered only in the chain of the Stockhorn. Beds of limestone and sandstone are met with at the Langeneckgrat (Ringgraben, Bärschwand, and

Allmend of Blumistein), as also at the Spietzfluh on the shores of the lake of Thun; they contain numerous fossils*, and form the boundary of the Trias. They have been called "Rhætic beds" (and have also received the names of *Contorta*-beds, from the presence in them of *Avicula contorta*, Kössener beds, Upper St.-Cassian beds, and Alpine bone-beds).

The Triassic marine deposits are more developed on the south-west frontier of Switzerland, and in the portions of Savoy adjoining the Swiss frontier. A band of gypsum and carbonaceous limestone extends from Bex to Morillon in Savoy, and to Villeneuve; further on, at Meillerie on the lake of Geneva, and on the banks of the Dranse above Thonon, Professor Heer meets with Rhætic beds which may be traced southwards as far as the Arve. Many bands of Triassic rocks which traverse Savoy give evidence of the existence of the Triassic sea in that country.

To the east of Switzerland a broad band of Triassic rocks penetrates from the Tyrol and Vorarlberg near Vadutz and Triesen as far as the Rhine, but does not extend into Swiss districts. To the north and east of Switzerland, the Trias spreads over the frontier mountains of the Prättigau (including Scesaplana, 9136 feet in height). From this point, Triassic rocks may be traced over the district of Davos to the Oberhalbstein, and over the Albula as far as the Engadine, where they commence again at Ponte and are continued to Sulsana; and from thence spread towards the east through the Camogaskerthal to Livigno and the neighbouring district as far as Scarlthal and Münsterthal. M. Albert Escher de la Linth has demonstrated that the limestone mountains which occupy the right side of the valley of the Engadine from Ponte to Remus belong to the Triassic formation.

At Vadutz, and also near Weissenbach and Thannberg, in the valley of the Lech, Professor Escher discovered the leaves of the *Pterophyllum Jægeri*, Br.; and in the latter locality he found the giant horsetail, *Equisetum arenaceum*—proving that at the period of the Keuper that district had not been submerged, whilst the sea had covered all the rest of the Alps, where the Triassic formation was deposited; additional evidence of this fact is given in the *Bactryllia*, marine algæ, and marine shells found in the alpine rocks. These remains belong either to the Muschelkalk or the Keuper; and several stages of deposits may be distinguished in them. The Muschelkalk has the appearance of a hard black limestone, which is particularly well-developed at the Virgloria Pass on the Rhätikon, and has in consequence received the name of the "Virgloria-bed of limestone." It splits into thin slabs, which take a good polish, and are used for making tables &c. This bed is widely diffused in the Vorarlberg and the Grisons, and contains a few fossils, of which the Encrinites and some Mollusca (such as *Terebratula vulgaris* and *Avicula socialis*) indicate the Muschelkalk. It is followed at the Virgloria Pass by very soft, blackish marl-shales, known as the "Partnach shales," because they occur in considerable quantity at Partnachklamm, near Partenkirchen, in Bavaria. They contain in great abundance an elegant *Bactryllium* (*B. Schmidii*, Heer, Pl. III. fig. 8), which has been found in many places in the Vorarlberg and the Grisons, and at the Virgloria Pass occupies whole slabs of the rock; they also contain a fine flat-shelled bivalve (*Halobia Lommelii*), as well as the *Chondrites prodromus*, Heer (Pl. III. fig. 10), discovered by Escher de la Linth on the west side of the valley of Alvier, south of Bürseberg, in the Vorarlberg.

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* See C. von Fischer-Ooster, "The Rhætic Rocks of the Environs of Thun," Bernese Transactions, 1869. M. Fischer refers to 6 species of Fishes, 1 Crustacean, 2 *Serpulæ*, 93 Mollusca, and 10 Radiata from these deposits.

The type of the *Chondrites prodromus* continues to our times in very similar forms and in all geological formations. It is a marine plant, the delicate fronds of which spread out into branches with parallel edges. In the Triassic species, the branches are twice bifurcated, of equal length, and obtuse at the extremity. The branches are slightly curved back, and form a sort of fork.

The Partnach shales are covered in the Vorarlberg and the eastern Grisons by a porous, black, or light-grey limestone, which sometimes attains a thickness of 500 to 600 feet, and is called the "Arlberg or Hallstätt limestone." It is followed by the sandstones containing the plants already enumerated, and here and there enclosing numerous marine shells (*Cardita crenata*, *Corbula Rosthorni*, &c.); these sandstones have much analogy with the sandstones of Raibl in Carinthia, to which they have been assimilated. But the chief portion of the Triassic rocks of the Swiss southern Alps consists of dolomite, a rock of a light or dark grey colour, composed of carbonate of lime and magnesia. It contains no fossils. Its geological age is therefore determined only by its position, which indicates its place to be between the Raibl beds and the *Contorta*-beds, the latter forming a most important horizon in the Vorarlberg and the eastern Grisons, characterized by the presence of small *Bactryllia* (*B. deplanatum* and *B. striolatum*, Heer, Pl. III. fig. 7, enlarged ten times) and of some widely distributed bivalves, such as *Avicula contorta, Plicatula intusstriata, Cardium austriacum*, &c. A light-coloured dolomite (the Dachstein limestone) overlies these shales, and is largely developed in the Alps of Salzburg and the Vorarlberg, where it contains a bivalve shell (*Megalodus triqueter*), the transverse section of which forms large heart-shaped fissures on the rock. Branching corals are not uncommonly found on the Rhätikon.

Like Merian, Escher, and Gümbel, Professor Heer refers the whole of these deposits, from the Partnach beds to the Dachstein, to the Keuper, on account of the fossils contained in these rocks; but the Austrian geologists classify them with the upper series of the Lias formation.

The *Bactryllia*, with the shells already mentioned, are widely distributed in the Italian Alps, showing that the Triassic sea extended to the east as far as the lake of Lugano. The range of mountains between Porlezza and Lugano, whose steep slopes come down to the north of that charming lake, belongs to the upper Trias, and with the same formation Monte Salvatore and Monte St. Giorgio are connected, which form the western limit of the dolomitic mountains. In these rocks the remains of 55 species of marine animals have been found, which leave no room for doubt as to their origin. Among these marine fossils are *Encrinus liliiformis, Halobia Lommelii* (delicately striated), *Halobia obliqua*, Hauer, *Chemnitzia tenuis*, Münst., and *Chemnitzia Escheri*, Hörn., *Ammonites luganensis*, Mer., and *Ammonites scaphitiformis*, Hauer, and other shells characteristic of the Trias, proving that the same Triassic fauna was distributed in Italy, Switzerland, and Germany.

Salt has been already mentioned as the most important product of the Triassic period; but in Switzerland gypsum also, in great measure, belongs to the Trias. It is found between the Muschelkalk and the Keuper, as, for instance, at Basle-Campagne, in the Jura of Aargau at Staffelegg, at Habsburg, at Niederweningen, Baden, Ehrendingen, Müllingen, Birmensdorf, and Gebensdorf, and also in the Münsterthal. It is obtained in considerable quantities in numerous localities, and is employed as manure and for various industrial purposes. In some places the gypsum contains sulphate of soda and sulphate of magnesia; and these salts form the basis of aperient mineral waters. The artificial mineral water prepared at Müllingen by soaking the gypsum in water contains in 1000 parts 32·4 of sulphate of soda and 1·5 of sulphate of magnesia; that of Birmensdorf comprises 7 of sulphate of soda and 22 of sulphate of magnesia. The mineral springs of Baden have been celebrated for ages; the water rises from a great depth, and probably derives its mineral constituents from the Keuper formation, whilst the sulphurous water of Schinznach and the iodized water of Wildegg probably spring from Triassic gypsum.

The Trias formation contains salt and gypsum; from it spring curative waters which annually benefit thousands of persons; it furnishes admirable building-materials, and by its decomposition, as marl, supplies an excellent manure. The Keuper districts are distinguished by rich meadows, fertile fields, and beautiful vineyards, which diffuse prosperity among the agricultural population.

Dolomite rocks, on the other hand, are merely converted by decomposition into a barren and sandy soil permeable by water, and where the dolomite exclusively forms the land, as among the limestone-mountains of the Vorarlberg and in the southern lateral valleys of the Lower Engadine, the vegetation is very poor; the trees and bushes are stunted, the meadows and pastures scantily clothed with herbage, and the higher regions completely arid. Some dolomitic districts in Switzerland, such as the Mora valley, which leads from St. Giacomo to the Münsterthal Alp, are destitute of vegetation, and present a desolate spectacle from the lowest part of the valley to the rugged summit of the mountains.

CHAPTER III.

SCHAMBELEN IN THE CANTON OF AARGAU, AND THE LIAS FORMATION IN SWITZERLAND.

In former times the ancient town of Vindonissa stood on a pleasant hill, near the meeting of the waters of the Reuss, the Limmat, and the Aar. A few ruins now remind the traveller where that Swiss fortress had been placed, and call to his remembrance the past splendours of that once important city.

Not far from the same locality Königsfelden awakens, in the Swiss, recollections of the middle ages, and remains as a memorial of a sanguinary scene in the history of the German emperors.

In the same vicinity, if we follow the road which borders the left bank of the river Reuss, we traverse charming meadows and a delicious forest, until we arrive at Müllingen. Thence, after half an hour's walk, we come upon a marl-deposit bearing the name, which also belongs to the neighbourhood, of Schambelen or Tschembelen.

There, on the left bank of the Reuss, we meet with a greyish-black marly and slaty rock, surrounded with brushwood; the rock readily decomposes on exposure to the rain and air, and forms a soft mass, which is exported for manure. The marl easily spreads about in friable fragments. Originally the strata were deposited in a horizontal position; but geological upheavals have raised the beds so as to make them nearly perpendicular. The deposit is 35 feet in depth*.

On the north the marl-rocks are bounded by the upper Keuper (a marly dolomitic limestone); and on the south there is a very hard limestone bed, 10 feet in depth, which contains many Ammonites (*A. Bucklandi*), Belemnites (*B. acutus*), and oysters (*Gryphæa obliqua*). This limestone stratum, we shall see further on, belongs to the Lias, which constitutes the lower part of the great Jurassic formation.

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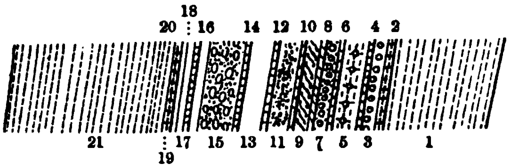
* [In 1874 Professor Heer informed the Editor, that since the visits described in this chapter the rocks had fallen at Schambelen.—Ed.]

The marl rocks of Schambelen therefore lie between the Keuper and the Gryphite limestone, and belong to the lowest and oldest portion of the Lias. The time of their formation followed immediately upon that of the Keuper.

Homogeneous as these rocks appear, we soon find, on closer examination, that they consist of a great number of strata which show considerable differences in the fossils they contain, and therefore leave us no room to doubt that their formation occupied a long time, and that while it was in progress many changes took place in the vicinity. The section (fig. 32) shows us these beds, which may be distinguished as follows, from below upwards:—

Fig. 32.



Section of the Schambelen rocks.

1. A marly bed about 6 feet thick, resting immediately upon the Keuper dolomite, containing iron-pyrites and isolated hard nodules, but scarcely any fossils. Only a few fragments have been found in it of a Brachiopod shell (*Rhynchonella costellata*).
2. A soft bed, 5 inches thick, with small brittlestars (*Ophiuri*). Some Echinids, bivalve shells (*Lima pectinoides* and *Lucina problematica*), and an Ammonite (*A. angulatus*) occur, but very rarely.
3. A bed, 1 foot thick, with Ammonites (*A. angulatus, A. longipontinus*) and a few Crustacea (*Glyphea Heerii* and *Penæus*).
4. A hard sandy bed, scarcely 1 inch thick, with small bivalves (*Lima pectinoides*).
5. A bed of soft marl, 1½ foot thick, with numerous Echinids

(*Diademopsis Heerii*, Mer.), old and young often united, as if in families, and with their spines still attached.

6. A hard bed about ½ inch thick, here and there containing fish-scales and carbonized wood.
7. A bed, 1 foot thick, with Echinids, prawns, Ammonites (*A. planorbis*, *A. angulatus*, and *A. longipontinus*), and a few rare insects (*Gyrinus troglodytes* and *Byrrhidium troglodytes*).
8. Like No. 6, but about 7 inches thick, with numerous remains of Pentacrinites (*P. angulatus*, Opp.), and a few Echinids, fish-remains (*Pholidophorus lacertoides*), and Crustacea. Much iron-pyrites.
9. A very soft marl, 1 foot thick, containing numerous Crustacea (*Glyphea*, *Eryon*, and *Penæus*), a few Ammonites and fishes (*Pholidophorus Renggeri*), and a very few insects (*Gyrinus atavus*, *Hydrophilites interpunctatus*, and small Carabidæ).
10. A thin hard bed (2 inches) like No. 8.
11. An insect-bed. In the soft greyish-black marl, 1½ foot in thickness, of this stratum are found a remarkable number of species of insects, partly aquatic and partly belonging to the land. No marine animals occur in this bed; but there are traces of land-plants and of carbonized wood.
12. A hard bed, 1 inch thick, with much iron-pyrites.
13. A soft marl, 7 inches thick, which readily breaks up into small irregular fragments. It contains a good many Ammonites (*A. longipontinus* and *planorbis*), fishes, and prawns, a few insects (White Ants, Grasshoppers, Cockroaches, *Gyrini*, and Carabidæ), and ferns (*Camptopteris Nilssoni*).
14. A very soft, smooth, shaly marl, 1 inch thick, containing many black scales and a few Crustacea (*Penæus*).
15. A marl-bed, 3 feet thick, with marine shells (*Inoceramus Weissmanni*, *Lucina problematica*, *Rhynchonella*, *Cypricardia*, and *Ammonites angulatus*), fishes (*Pholidophorus lacertoides*), and a few insects (*Buprestites* and *Byrrhidium*).
16. Black marl, 8 inches thick, containing numerous *Cardiniæ* (*C. Heerii*, May.), besides *Inocerami*, Crustacea (*Glyphea*),

and a few insects (White Ants, Grasshoppers, Buprestidæ, *Gyrini*, *Byrrhidia*, and Carabidæ).

17. A hard bed, 1 inch thick, with small specimens of *Lima pectinoides*; many nodules and threads of iron-pyrites.
18. A soft marl, 5 inches thick, containing here and there carbonized fragments of wood, pinnæ of ferns, and large seaweeds, with fish-scales, a few insects (*Glaphyropterus*, Elateridæ, Carabidæ, and Bugs), bivalve shells (*Cypricardia* and *Lucina*), and Crustacea (Shrimps and *Glypheæ*).
19. Rough sandy marl, 4 inches thick, with many specimens of *Lima gigantea.*
20. A light-coloured marl, 5 inches thick, with large and small brittlestars (Ophiuri), Echinids, small *Limæ*, and a few *Inocerami*, *Lucinæ*, *Cypricardiæ*, and some remains of Pentacrinites.
21. Another light-coloured marl, 9 feet in thickness, without any fossils, immediately beneath the Gryphite limestone.

Researches carried on for ten years at Schambelen have enabled Professor Heer thus to fix the order of the various deposits. They show us that the fossiliferous beds (2–20) lie between non-fossiliferous beds, and that the latter form nearly one half of the whole mass. It is further to be noted that of the fossiliferous beds only the uppermost and the lowest contain the brittlestars, and the lower six beds only marine animals; insects appear first, but very rarely, in the seventh bed, and then again, also rarely, in the ninth stratum; and it is only in the eleventh bed that insects occur in great numbers. They then disappear, to occur again for the last time in the eighteenth bed, where their numbers are but few. The eighteenth bed, like the seventh, contains also marine animals, which are entirely wanting in the eleventh bed.

From the contents of the different strata of this rock we learn that it must have been formed in a quiet bay, protected from the force of the waves either by a chain of hills projecting into the sea or by a reef of rocks. It is only thus that we can explain the wonderful preservation of the animals, whose remains were quietly covered up by mud settling in the water. That there was dry land in the neighbourhood is proved by the numerous insects which occur; for, although one genus of insects (*Halobates*) lives in the open sea, and some others (*Gyrinus, Ochthebius, Hydræna,* and *Calobius*) in the brackish or salt water around the coasts, those found at Schambelen belong to genera whose allies at the present day live either exclusively on dry land or in fresh water. It is true that in most cases the marls have preserved only the wings of the insects; but in a considerable number the head, thorax, and elytra (wing-cases) are still united as during life. This proves that these little creatures cannot have been carried far by water; otherwise they would not be so well preserved. For the same reason they must have been quickly covered with mud, and thus protected from decay. It is remarkable, however, that the land-plants which we find in the same beds with the insects are in small fragments, although their nervures or fibres may be well distinguished. The insects and plants do not occur as mere impressions, but their substance itself is preserved, and some leaves may even be detached from the stone.

The rapid covering of the fragments of plants and insects manifestly proves that the water must have contained much earthy matter, which may be explained by the assumption that a river flowed into the bay, carrying with it mud, by the deposition of which the marly rock was gradually formed. The bay, the bottom of which was formed by the Keuper dolomite, was probably at first of very considerable depth; it possessed no animals, and the mud first deposited upon it seems to have come from a region of the land which had been a desert, so that the first layer (1) was nearly unfossiliferous.

Marine animals then took up their abode at the bottom of the water—first delicate brittle starfish and a few sea-urchins, bivalve Mollusca, and large Ammonites; a little later the Crustacea were added, the sea-urchins became more abundant, and the brittle starfish disappear (2–6). In the seventh bed insects make their appearance, but only a few species. Probably the forest was still distant from the coast, and did not closely approach it until the time of the formation of the eleventh bed; for in it the forest-insects, especially those which feed on plants, occur in numerous species. With them are many insects which could have lived only in fresh water; and these probably were carried down by a river to its mouth, where they lived for a time in the brackish water, just as at the present day many freshwater insects follow the rivers down into the sea. In a similar way the occurrence of small *Gyrini*, associated with undoubted marine animals, in beds 7, 9, and 13 must be explained. But in the eleventh bed the marine animals have disappeared; and probably at this period a gradual upheaval of the bottom took place, and the bay was protected from the incursions of the sea by a wall of rock or a sand bank, so that its brackish water was gradually converted into fresh water, and became the residence of many freshwater insects.

Again, however, the bottom began to sink, the sea broke in, the insects became again very rare, whilst marine crustacea and mollusca, and finally the sea-urchins and brittle starfish resumed their place. It is remarkable that the animals reappear in nearly the same order in which they had disappeared, and that at the top there is again a non-fossiliferous marl, indicating that, by a gradual depression, dry land had been removed to a considerable distance, so that its products no longer reached this part of the sea: but at the same time the conditions here prevalent were unfavourable to marine animals also; for they disappeared, and we have before us merely the deposits of a depopulated sea.

The thin bands of hard sandy marl (4, 6, 8, 10, & 12) which lie between the softer masses are worthy of notice; they contain only marine fossils, and were probably formed by materials driven into the bay from the sea during storms. Afterwards these hard strata served to protect the softer subjacent marls from the invasion of the sea.

A calm and tranquil bay must thus be imagined to have been the birth-place of the Schambelen rock, the layers of which form the leaves of that ancient document which tells us of the plants and animals of the Liassic period. It vividly reminds Professor Heer of a similar bay on the shores of Madeira, which he often visited to observe the strange economy of the inhabitants of the sea. In most places the shores of that island dip steeply into the ocean, and the surf that breaks upon them renders life almost impossible; and even when the shore ascends more gently from the water, it is barren, as the constant agitation of the water prevents the development of animals and plants. But where reefs of rock break the surf, and the water inside this barrier is protected from the violence of the waves, there is an abundance of life. Such a place occurs at the Gorgulho, about two miles from the town. Here among broken rocks some quiet basins are formed, which are fed by the spray of the surf, and are deluged with water during storms. The rocks surrounding the basin are completely covered with Cirripedes (*Balanus punctatus*); among which limpets (*Patellæ*) cling to the rocks, and *Littorinæ* seek their food. The water in the basin is quite clear and transparent, so that the bottom can be seen. Here the globular sea-urchins sit in their round holes, moving their brown or violet spines to and fro; we see also starfish with long arms, as well as the *Ophidiaster ophidianus*, Lam., and *Stellonia Webbiana* and *tenuissima*, D'Orb.; and with them are associated the curious brittle starfishes, whose long, thin arms are covered with coloured scales; and rooted to the bottom are many seaweeds, such as the delicate *Padina pavonia* and bushes of dark-green *Dasycladi*. Upon these feed a multitude of Mollusca (*Purpura hæmastoma* and many species of *Turbo* and *Trochus*), crawling slowly over the submarine pasture.

Other shells are seen moving briskly about; but when we examine them, we find that the original mollusk is not the cause of this movement, but that a curious red crustacean (*Pagurus callidus*, Roux) has killed the former owner and seized upon the shell for his own residence, which he carries about with him. Other Crustacea, such as crabs, move about; the *Plagusiæ* and prawns (*Palæmon*) skilfully progress through the water; and brilliant little fishes (*Julis turcica*) cross and recross the basin in all directions. The surface of the water is partly covered with Confervæ, in which numerous little water-beetles (*Calobius Heerii*, Woll.) take up their abode, and play about among the green fibres of the plants. Thus, in a small space, we find numerous individualities manifesting themselves in different forms, and having a general resemblance to the former condition of Schambelen.

Sea-urchins and brittle starfishes of the same size with those of Madeira played about in the Schambelen sea; at the bottom of the water were Crustacea, and small prawns moved along;

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[illegible]
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[illegible], whose [illegible] are
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[illegible] about [illegible] we [illegible]
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[illegible], [illegible] the [illegible] seized [illegible] the
[illegible] residence [illegible] carries about with him.
[illegible] as [illegible] move about; the *Plegusia* [illegible]
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Burri & Jeker

numerous Mollusca and small fishes frequented the branches of seaweeds; and here also little water-beetles swam near the surface of the water, on which *Gyrini* described their graceful curves.

The Plate of the submarine life at Schambelen is an attempt to give an idea of the former inhabitants of that locality. In the foreground we see the bivalve Mollusca (*Limæ*, and *Inocerami* and the *Terebratulæ* suspended by their filaments), the brittle starfishes, the spiny sea-urchins, Ammonites, and Crustacea (*Glyphea*, *Eryon*, and *Penæus*). Among them are the tufts of seaweeds, the delicate forms of *Chondrites* and *Zonarites*, and the firm ribbons of *Fucoides rigidus*, between which the little fishes (*Pholidophorus helveticus*) play about. On the left side we see the long-stalked Pentacrinites, and opposite to them a large seaweed (*Fucoides procerus*), whilst from the background the curious shark-like *Acrodus* shows himself as a frequenter of this peaceful locality.

We must not forget that the plants and animals of the Schambelen sea-basin differ from those now living, not only specifically, but also, for the most part, generically: the same fundamental types have subsisted; but the forms have changed for thousands upon thousands of years. To demonstrate this we must examine the organized world of Schambelen more closely. In all, 22 species of plants and 182 of animals have been there observed. The animals comprise 11 Fishes, 1 Reptile, 143 Insects, 6 Crustacea, 17 Mollusca, and 4 Radiata.

I. Marine Plants.

Marine plants are not so plentiful as might have been expected, probably because their soft gelatinous texture is unfavourable to their preservation. Nevertheless we find among them some very delicate, finely ramified organisms, which, when alive, covered the bottom as if with turf. *Chondrites liasinus*, Heer (Pl. IV. fig. 2), had a repeatedly furcate frond, with the last ramifications short and nearly equal in length; whilst in *Zonarites chambelinus*, Heer (Pl. IV. fig. 1), the frond is palmate from the base and divided into branches of nearly equal breadth, which fork and subdivide until they terminate in short narrow ramifications. ***Fucoides rigidus***, Heer, forms thick, leathery ribbons, divided at the end into two short, obtuse branches; and ***Fucoides procerus***, Heer, has its frond divided into branches of 2 inches width, which probably attained a considerable length. This species in size resembled the ***Laminariæ*** of the present seas, and perhaps belonged to the same genus. It occurs in great quantities, but imperfectly preserved, in the eighteenth bed of the Schambelen. ***Münsteria*** (***M. antiqua***, Heer, Pl. IV. fig. 19) is the first reprcsentative of a form of Algæ which took an important place in the Jurassic sea and in that of the Flysch; it is characterized by uumerous transverse striæ, which give the fronds a ringed appearance. The species found at Schambelen is small, and shows no points between the striæ.

Besides these Cryptogamic plants, a species of grass of the sea, Grasswrack, ***Zosterites tenuestriatus***, Heer (Pl. IV. fig. 17), is found; at least it seems probable that some long leaves, with parallel sides and obtusely rounded ends, and traversed by numerous longitudinal striæ, were derived from a plant of this kind; for they belong to the family of the Naiades.

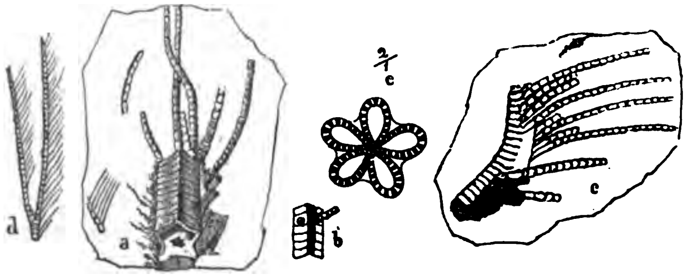
II. Marine Animals.

Thirty-nine species have been found at Schambelen, namely 4 Radiata, 17 Mollusca, 6 Crustacea, 1 Saurian, and 11 Fishes.

a. *Radiata.*

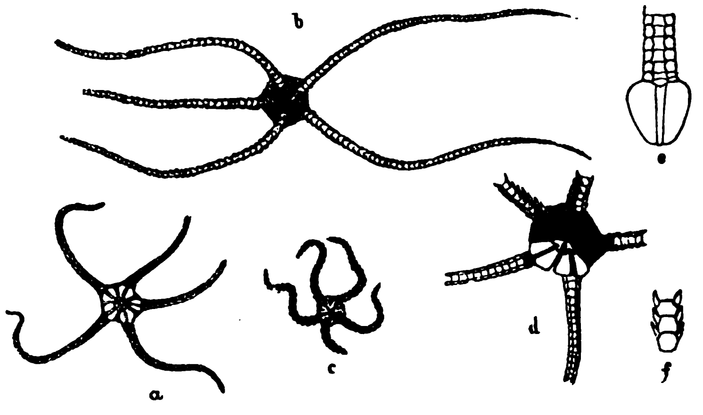
In place of the Lily Encrinite, described p. 43, a remarkable Pentacrinite (***Pentacrinus angulatus***, Opp.) makes its appearance here. It also has a long, jointed stem, which, however, represents a pentagonal column with very sharp angles (fig. 33, *a*), giving off here and there thin, jointed branches (fig. 33, *b*); at the summit of the column is a crown composed of five arms, which soon bifurcate, and divide again further on. The joints of the arms are cylindrical (fig. 33, *c*); and the thin extremities are furnished with a row of long delicate filaments (*pinnulæ*, fig. 33, *d*). No entire crowns have yet been found at Schambelen; but many fragments of stems and portions of the crown occur. Single joints of the stem are more abundant; and these exhibit on their articular surfaces an elegant, flower-like marking (fig. 33, *e*). The Pentacrinites, like the Lily Encrinites, probably lived together in colonies, and were attached by their long stems* to the rocks.

Fig. 33.



Pentacrinus angulatus, Opp. *a.* Portion of the main stem. *b.* Insertion of the branches. *c.* Portion of an arm with its branches. *d.* Arm with the pinnules. *e.* Section of the stem, magnified 2 diameters.

Fig. 34.



Ophioderma Escheri, Heer. *a.* Small specimen, upperside. *b.* A middle-sized specimen, underside. *c.* A young animal. *d.* Two arms and the corresponding plates of the disk, from above; the other three arms and the rest of the disk are shown by the impression of the underside. *e.* Base of an arm, from above. *f.* Portion of an arm, from beneath.

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* Of an allied species (*P. subangularis*, Mill.), stems are known 35 feet in length.

The brittle starfishes (*Ophiurida*), which were nearly allied to them, have no stems and live free in the water. They are characterized by their five long, finely pointed arms, covered with coloured scales. At Schambelen we have an elegant species, *Ophioderma Escheri*, Heer* (fig. 34), which closely resembles the *Ophiura texturata*, Lamk., of the European and southern seas. It occurs in all stages of growth.

Equally remarkable is a sea-urchin (Echinid) from Schambelen, *Diademopsis Heerii*, Merian (Pl. VI. fig. 1), which occurs almost perfect and still armed with its spines. Thus this type is presented to us in so well-preserved a state that we may use this species for the elucidation of a form of animals which makes its first appearance in the earliest periods, and has always constituted an essential part of the marine fauna. A glance at Pl. VI. fig. 1, *b–h*, shows us the species from Schambelen, of various sizes, from 3½ lines to 1 inch in diameter. We see that the shell (test) is composed of numerous plates forming ten bands. On five of these bands, there are at each margin two rows of small apertures (Pl. VI. fig. 1, *d*) for the passage of the membranous feet (or *ambulacra*), which probably extended beyond the spines and enabled the animal to move about. The bands which bear these apertures are called the *ambulacral areas*; and in the present genus they traverse one half of the test, and are furnished with two rows of little tubercles (Pl. VI. fig. 1, *g*). Between each pair of ambulacral areas, we find two rows of imperforated plates, forming the *interambulacral areas*. In the present species each plate bears two rows of smooth tubercles, rather larger than those of the ambulacral areas; the outer row alone reaches the summit of the test. To these tubercles are attached the finely striated spines, or radioles (Pl. VI. fig. 1, *e*;

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* This is very nearly allied to *Ophioderma Egertoni*, Brod., from the Upper Lias of Lyme Regis (see Geol. Trans. London, vol. v. p. 174, pl. 12. figs. 5, 6). In the English animal, the disk is larger in proportion, and the lateral scales reach the middle of the back of the arms. In *Ophioderma Escheri* the thin, cylindrical arms are covered with four rows of scales, of which the lateral overlap both above and beneath (fig. 34, *e, f*, see page 71). The middle of the upper part of the disk consists of five small cordate plates, round which are ten larger ones, placed in pairs covering the base of the arms (fig. 34, *a, d*). On the lower surface of the disk (fig. 34, *b, d*) the five-rayed star indicates the mouth.

enlarged, *f*). The mouth is provided with five pointed teeth (Pl. VI. fig. 1, *b*), which meet in the middle of the aperture. Of this species, we find at Schambelen whole familes together, old and young; so that they undoubtedly lived in this spot; of a second species (*Cidaris psilonoti*, Quenst.), only separate spines have hitherto been discovered.

b. *Mollusca.*

Where the rocks enclose the remains of marine animals thrown on shore by the surf, we often find in them whole masses of shells mixed confusedly together. This is not the case at Schambelen. Mollusca are not uncommon there; but they generally occur singly, and an accumulation of numbers is only noticed in the case of the little *Limæ*. The number of species also is small. It is evident that this locality did not suit them, probably because the water was too muddy and brackish.

The most striking species are the Ammonites, the most abundant of which are *Ammonites longepontinus*, Fr., and *A. planorbis*, Sow.—the latter a small flat species really resembling a *Planorbis* (fig. 36), the former attaining a considerable size.

Fig. 35.

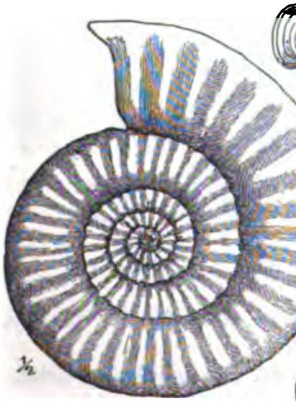


Fig. 36.

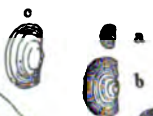
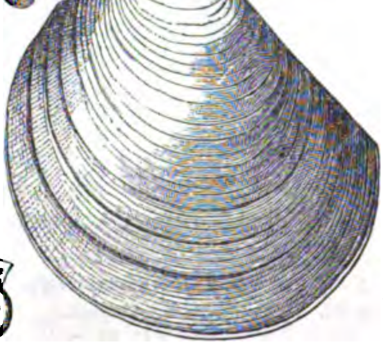


Fig. 37.



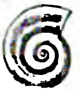


Fig. 36.

Fig. 35. *Ammonites longepontinus*, Fr.
Fig. 36. *Ammonites planorbis*, Sow.

Fig. 37. *Lima gigantea.*

The specimen figured (fig. 35) is nearly 4 inches in diameter; but others were much larger, probably measuring more than a foot across. The shell is traversed by strong transverse ribs, which become flattened and disappear towards the back, whilst in the nearly allied *A. angulatus*, Schl. (which also occurs, although more rarely, at Schambelen), the ribs reach the back. In the outer whorl of large specimens of both species the shell is smooth. On many of the shells we see an elegant marking (fig. 35, *b*), which is produced by the junction of the septa with the shell, and, as already stated (p. 45), is characteristic of the true Ammonites.

In many Ammonites the aperture of the shell was closed by an operculum (*Aptychus*), represented in fig. 36, *c*, from *A. planorbis*, in which species it consist of a single plate. Some small, black, striated scales of a similar form (fig. 36, *a*; enlarged, *b*), which are very abundant at Schambelen, and which Professor Heer has also seen in the Lias of Lyme Regis, are probably the opercula of young animals. In other species the operculum consists of two plates.

Fig. 35 B.

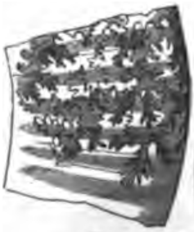


Fig. 43.

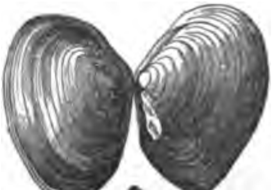
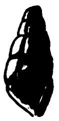


Fig. 44.



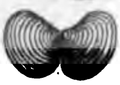


Fig. 38.

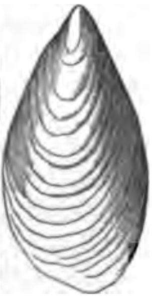


Fig. 39.

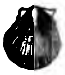


Fig. 40.

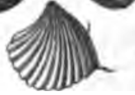


Fig. 41.

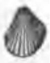


Fig. 42.

Fig. 35 B. *Ammonites longepontinus*, Fr.
Fig. 38. *Lucina problematica*, Terq.
Fig. 39. *Inoceramus Weissmanni*, Opp.
Fig. 40. *Pecten disparilis*, Quenst.
Fig. 41. *Rhynchonella costellata*, Piet.
Fig. 42. *Lima pectinoides*, Goldf.
Fig. 43. *Cardinia Heeri*, K. May.
Fig. 44. *Rissoa liasina*, Dunk., enlarged.

Associated with the Ammonites at Schambelen is a very small marine univalve shell, *Rissoa liasina*, Dunk. (fig. 44), characterized by its elegant longitudinal ribs. The most abundant bivalve is the little furrowed *Lima* (*L. pectinoides*, fig. 42) already referred to; but *Lima gigantea* (fig. 37) is by no means rare, especially in bed 19, in which alone *Modiola psilonoti*, Quenst., has hitherto been found. The thin-shelled *Cypricardiæ* (*C. cuneolus* and *C. minuta*, May.), the *Lucina* (*L. problematica*, Terq., fig. 38), and the *Cardiniæ* (*C. Heerii*, May., fig. 43, with a thin shell) are distributed through most of the beds; these Mollusca resemble those of the Swiss fresh waters (the species of *Unio* and *Cyclas*). The Scallops, characterized by their flat shells, eared at the hinge, are rare and small (*Pecten sepultus*, Quenst., *P. redemptus*, May., Quenst., Jura, Pl. V. fig. 14, no. 10, and *P. disparilis*, Quenst., var. ?, fig. 40). The Scallops swim through the water by opening and closing their valves, and have in consequence received the name of "Sea-Butterflies," which is the more suitable as their shells often exhibit bright and varied colours. The clumsy *Inocerami*, on the contrary, were fixed to the muddy bottom; one species (*Inoceramus Weissmanni*, Opp., fig. 39) occurs in most of the beds. *Rhynchonella costellata*, Piette (fig. 41) is confined to the lowest stratum. It belongs to the class of the Brachiopoda, which took an important place among the Mollusca of former ages, and are characterized by the possession of a pair of arms, usually rolled up into a spiral and supported by a peculiar calcareous framework. The two dissimilar valves have generally hinge-teeth and fit each other accurately; they could not open widely, as they are destitute of the elastic ligament of other bivalve shells. After death they usually remain united, so that the shells are almost always closed in the fossil state. In the *Terebratulæ* and *Rhynchonellæ* the larger or ventral valve is furnished with a curved beak, with an aperture through which issue fibres serving to attach the animal. Very few living species are known; but several localities of the early seas were filled with them.

c. *Articulata.*

The Articulata are represented by five crayfishes and an Amphipod. The former belong to three genera, one of which (*Eryon*) first appears in the Trias, is widely diffused in the Lias and Oolites, and disappears with the Chalk; the second

(*Glyphea*) first appears at Schambelen, develops into numerous species in the Middle and Upper Oolite, and then vanishes; whilst the third (*Penæus*) also shows itself first in the little bay of Schambelen, and may be traced down to the present time. There are, therefore, three important genera, representing three principal types of the Liassic and Oolitic seas.

In general aspect the *Glypheæ* may be compared to the Swiss crayfish; but none of the legs have nippers, they terminate in simple claws (Pl. VI. fig. 2, *b*). They had very finely jointed and rather long antennæ. The carapace is large, narrowed and produced into a pointed rostrum in front, and divided by a deep transverse furrow into two parts, of which the anterior bears five longitudinal ridges, whilst the larger posterior part is divided by a central longitudinal furrow into two halves, and each of these again by an oblique furrow. The abdomen consists of smooth, shining segments, the last of which bears large oval caudal plates. The most abundant species at Schambelen (*Glyphea Heerii*, Opp., Pl. VI. fig. 2) is of the size of the Swiss river-crayfish, and has a closely punctured carapace; whilst the carapace in a second much rarer species (*G. major*, Opp.) is not punctured, but furnished with tubercles at the margin.

In the genus *Eryon* the anterior feet are furnished with nippers (chelæ), the antennæ are short, the carapace is large and slightly excavated in front, and the short abdomen bears large caudal plates. A fine species from the Schambelen (*Eryon Escheri*, Opp., fig. 47) is characterized by its slender nippers with curved fingers, its finely granulated carapace, and the almost spine-like tubercles which are placed on the middle of the abdominal segments.

Penæus has quite a different aspect, and belongs to the group of shrimps and prawns. The Swiss species (*Penæus liasicus*, Opp., fig. 45) reminds Professor Heer of the common prawn (*Palæmon squilla*); but it is still more nearly allied to the much larger species (*Penæus sulcatus*, Ol.) which is taken in great quantities in the Mediterranean. The Schambelen species is smooth and of a shining brown colour; several specimens generally lie together in the same slab; so that, like the common prawns, they lived in society. They are also much bent, sometimes regularly curved into a ring (fig. 45, *c*). The carapace is produced into a simply denticulated spine in front; when seen from above, it is very broad (fig. 45, *a*), and rounded at the sides.

Fig. 45.

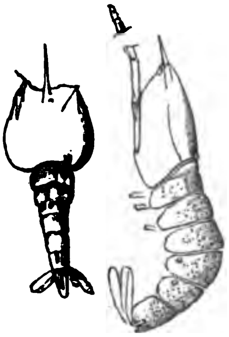
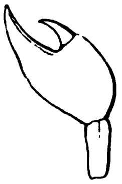


Fig. 46.



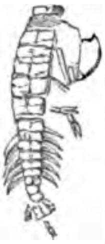
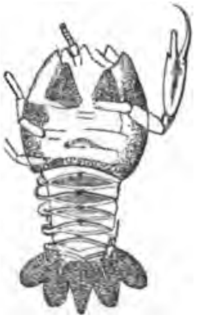


Fig. 47.



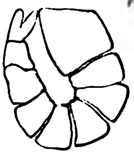


Fig. 45, *c*.

Fig. 45. *Penæus liasicus*, Opp.: *a*, from above; *b*, from the side; *c*, curled up.
Fig. 46. *Opsipedon gracilis*, Heer: *a*, enlarged three times; *b*, a chela strongly magnified.
Fig. 47. *Eryon Escheri*, Opp.

The *Penæi* and *Glypheæ* are the commonest Crustacea at Schambelen. A little yellowish-brown Amphipod (*Opsipedon gracilis*, Heer, fig. 46, enlarged three times) occurs there very rarely. It has a distinctly jointed flat abdomen, the segments of which are furnished with pointed appendages. The last joint of the feet seems to have acted as a nipper (fig. 46, *b*).

d. *Marine Fishes.*

Fish-scales are plentiful in the different beds at Schambelen; but entire fishes very rarely occur. Eleven species have been distinguished, belonging to two groups, the Sharks and the Ganoids. Of the former two genera occur, namely, *Hybodus* and *Acrodus*; but hitherto only their teeth have been found. In *Acrodus* the tooth (fig. 48, *A. minimus*, Ag.) has a sharp median ridge, towards which fine, sharp wrinkles run; the middle ones are forked towards the base, and unite in a slightly projecting central tubercle. The investigations of Agassiz have shown that these teeth belonged to a large fish, most nearly allied to the

Port-Jackson shark (*Cestracion Philippii*, Lep.). The *Hybodus* had very sharp teeth (fig. 49 of *H. reticulatus*), with several

Fig. 54.

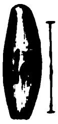


Fig. 48.

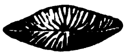
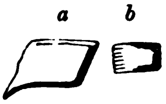
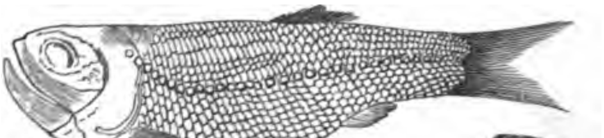
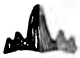
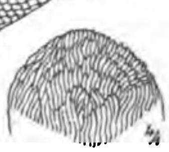


Fig. 51.









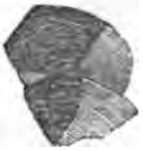


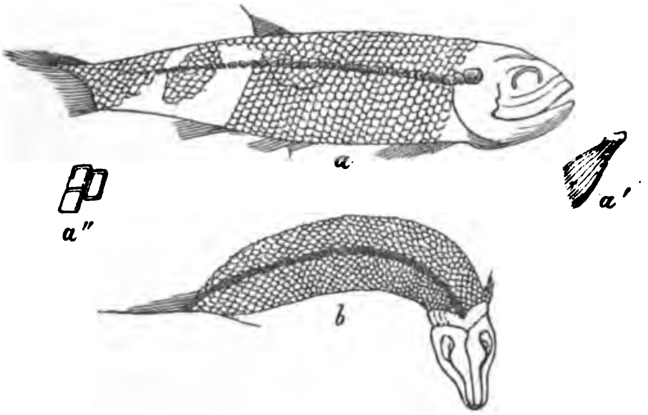
Fig. 49. Fig. 50. Fig. 52. Fig. 53.

Fig. 48. *Acrodus minimus*, Ag. Fig. 49. *Hybodus reticulatus*, Ag.
Fig. 50. *Pholidophorus Renggeri*, Heer. Fig. 51. Scales of *Semionotus*.
Figs. 52, 53. Scales of *Ptycholepis*? 52, the upper half of a scale, slightly magnified; 53, two imperfectly preserved scales, nat. size.
Fig. 54. Tooth of a Saurian.

conical points, the middle about three times as large as the rest; sharp wrinkles run down from the points. This fish, which, according to Agassiz, reached a length of from 6 to 7 feet, had a large mouth closely armed with such teeth as are described above; like the *Acrodus*, it was a voracious fish of prey and the terror of the little harmless fishes which swam about in the bay of Schambelen.

All the lesser fish belong to the Ganoidei, a group characterized by their shining enamelled scales. The most important genus is *Pholidophorus*, which was distributed through all the Lias seas. They were little spindle-shaped fishes of a herring-like aspect; their backbone was composed of round vertebræ without ribs; they had small fins, and the caudal fin was forked into two equal lobes. Five species have been obtained at Schambelen; one of them (*P. Renggeri*, Heer) is represented in fig. 50. Its body is thickened considerably behind the head, close to which the two pectoral fins are placed; the dorsal fin stands opposite the space between the ventral and anal fins. The shining black scales are rather elongated on the fore part of the back, but become shorter behind. Those of the ventral part are also smaller, but still in regular rows. A second species (*P. helveticus*, Heer, fig. 54 B) is the most abundant fish at Schambelen. Its rhombic polished scales are smaller on the ventral part, and become shorter and irregular towards the tail. The body is not thickened in the middle; and the dorsal fin is placed opposite the ventral.

Fig. 54 B.



a. Pholidophorus helveticus, Heer. *b. Pholidophorus lacertoides*, Heer.

Of two other genera only the scales have been found. Those represented by fig. 51 belong probably to *Semionotus*; and those shown in fig. 53 and, slightly enlarged, fig. 52, perhaps to *Ptycholepis*. The latter are abundant at Schambelen, and are characterized by the shining yellowish-brown curved warts which cover the upper parts of their bodies. All these fishes belong to genera which disappeared before the Tertiary period.

e. *Reptiles.*

Only one species has been found at Schambelen; and this is represented only by a tooth (fig. 54), which seems to indicate an *Ichthyosaurus*. It is spindle-shaped, covered with shining enamel, and furnished in the middle with abbreviated irregular furrows.

III. Land Plants.

The scanty remains of land-plants contained in the marls give us a very incomplete notion of the vegetation of the dry land. Trunks of trees converted into coal are not uncommon; but the remains of leaves are rare, and generally so broken that we are led to conclude that they were brought from a considerable distance, and that the shore was a desert. But this view is contradicted by the abundance of land-insects, chiefly belonging to plant-eating groups, although the forests may have been at some distance and the insects, with wood and rubbish, may have been carried down into the bay from time to time by floods.

The trunks of trees belong chiefly to the Cycads, as appears from their obtusely rounded summits and the large scales with which they are covered (Pl. V. figs. 8, 9). Only a few indistinct remains of leaves which can be referred to the above family have been preserved (Pl. IV. figs. 12–14, and Pl. V. fig. 10); they may have belonged to *Pterophyllum* and *Nilssonia*. With these Cycads are associated two Conifers. Of one of them, *Araucarites peregrinus*, Lindl., a fine twig has been discovered (Pl. IV. fig. 15). It closely resembles the *Araucaria imbricata* from Chili. The twigs are densely covered with stiff, imbricated, pointed leaves, having a sharp median ridge; and the trees were probably large and much branched. The second Conifer (*Thuites fallax*, Heer, Pl. IV. fig. 16) had opposite leaves, like the "*Arbor vitæ*" of our gardens, which were furnished with a median ridge, and usually terminated in an incurved point. These two Conifers and the Cycads appear to have been the only trees in the forest.

The herbage covering the ground consisted of ferns, which remain only in small fragments (Pl. IV. figs. 3–9); but the arrangement of the veins is so characteristic that the species can be determined by its means. One species (*Phlebopteris polypodioides*, fig. 8) has also been found in the Lias of England and Halberstadt. It had large pinnate fronds, and resembled the *Woodwardiæ* of the present day. Another very abundant species (*Camptopteris Nilssoni*, Sternb., fig. 5) is remarkable for the arrangement of its irregular veins and for its coarsely toothed fronds. Of the species of *Pecopteris*, one (*P. debilis*, Heer, fig. 4) had the lobes of the frond very narrow, and deeply but obtusely toothed. This species reminds Prof. Heer of the living *Gleicheniæ* of the tropics, while another (*P. osmundoides*, Heer, Pl. V. fig. 6) resembles the royal fern (*O. regalis*). *Sphenopteris Renggeri*, Heer (Pl. IV. fig. 3), had smaller fronds, which were of a long oval form and notched. A small leaflet of a leathery consistence represents *Sagenopteris gracilis*, Heer (Pl. IV. fig. 9); it resembles the leaf of a leguminous plant; but the arrangement of the veins shows it to belong to a palmate fern.

Whilst these ferns grew in the shade of the old forest, the horsetails (*Equiseta*) and reeds probably bordered the bank of the river. Of the former (*Equisetum liasinum*, Heer) Professor Heer found the sheaths and nodes (Pl. IV. fig. 10). The sheaths have elongated, obtuse, punctate teeth (fig. 10, *a*); and the sections of the nodes (fig. 10, *c, d*) indicate a species scarcely larger than the largest of our living species (*Equisetum telmateja*). Of the reed (*Bambusium liasinum*, Heer) a fragment of a leaf has been found; its tip is shown in Pl. V. fig. 7. It is traversed by numerous longitudinal veins; and between each pair of strong veins there are from two to four very fine ones (Pl. V. fig. 7, and 7, *b*, enlarged), just as in our common reed (*Phragmites*); but there is no stout median vein. With these leaves are found long cylindrical stems with nodes (Pl. V. fig. 7, *c*), which probably belonged to the same plant. The substance of these stems is converted into coal, and their structure cannot now be ascertained; but we can see that the stems were not hollow. Fragments of narrow leaves, traversed by a strong median vein (*Cyperites protogæus*, Heer, Pl. IV. fig. 18), probably belonged to a species of Cyperaceæ, which grew in marshy places.

IV. LAND ANIMALS.

These are all insects, which, however, occur in great numbers. Professor Heer has obtained from Schambelen about 2000 specimens, belonging to 143 species. They are among the most ancient insects of Switzerland, and therefore possess much interest. This type of animals made its appearance in the Carboniferous period; but that formation has hitherto only furnished one Swiss species, and very few occur elsewhere. From the

Trias only two species are known (*Glaphyroptera Pterophylli* and *Curculionites prodromus*, Heer), discovered in the Keuper of Vadutz. In the Bunter Sandstone of Trelitz and Salzmunde three more have been found (*Legnophora Girardi*, *Chauliodites Picteti*, and *Ch. Zinckeni*). It is, however, in the Lias that numerous species of this class of animals first appear, with a diversity of forms, comprising genera often similar to those now existing. Professor Heer considers that Schambelen is the only locality on the continent where so many primæval insects have been preserved to our time. Fifty-six species of insects have been found in England in the Lower Lias; but the insects of Schambelen are much better-preserved and are more varied, so that this deposit is the most important locality for Liassic insects. The species hitherto found are distributed among the orders as follows:—

Orthoptera	7	species.
Neuroptera	7	,,
Coleoptera	116	,,
Hymenoptera	1	,,
Rhynchota (or Hemiptera)	12	,,

The Lepidoptera and Diptera are entirely wanting; and the Hymenoptera are represented only by a single small wing. The preponderance of the Beetles (Coleoptera) may be due to the circumstance of their hard elytra being better adapted for preservation than the soft wings of most other insects; and, in fact, it is chiefly the elytra of the beetles that have come down to us. But as the delicate membranous wings of the *Termites* have been preserved, there is little doubt that if the Diptera and Lepidoptera had lived in the Lias island, and fallen into the water like the other insects, some traces of them would have been found.

We must now examine these insects more in detail.

A. *Orthoptera.*

Of these, three species are cockroaches, three grasshoppers, and one an earwig.

The *Cockroaches* (Blattidæ) are very like the species known from the coal-measures, and form with them a genus (*Blattina*) distinguished from those of the present day by the longitudinal nervures rejoining in the anal area (the sutural margin). One of the species from Schambelen (*B. formosa,* Heer, Pl. VII. fig. 1; the wing, magnified, fig. 1, *b*) is nearly as large as the common cockroach (*Blatta orientalis*); the other two species (*B. angustata* and *B. media,* Heer) are considerably smaller. As these cockroaches made their appearance even in the Carboniferous period, and were then the most widely distributed and abundant of all insects, we must regard them as the patriarchs of the insect-world.

By studying the habits of the Swiss cockroaches, Professor Heer is enabled to throw some light upon the mode of life, in early days, of these animals.

The Blattidæ, or Cockroaches, form, in the interior of their bodies, regular egg-cases of comparatively large size and containing several eggs, which the mother carries about with her for some time or protects with an envelope. The eggs are therefore perfectly sheltered from danger, and may retain their vitality for more than a year. The newly hatched young are exceedingly active, and live for a time in society. They are very slowly developed; the common cockroach only attains maturity in its fifth year. It is therefore a long-lived insect, and is very tenacious of life, resisting even the fumes of sulphur, a peculiarity which may explain how these animals contrived to live during the Carboniferous period, when the air was surcharged with carbonic acid. All the Blattidæ are nocturnal animals; at night they seek their food, which consists of all sorts of vegetable substances.

Most of the coal-insects (Cockroaches and Termites) are nocturnal in their habits; and most of the coal-plants correspond with plants of the present day (ferns and club-mosses) which thrive under the shade of the forests. This is probably connected with the vaporous envelope which covered the earth during the Carboniferous period. The cockroaches of the Schambelen Lias island must have been supplied with food from the Cycadaceæ, whose trunks, no doubt, contained a supply of starch, like the trunks of their existing relatives. The decaying Cycads offered abundant nourishment both to the cockroaches and the termites; and as this type of plants (*Næggerathia*) appeared in the Carboniferous period, Professor Heer had no difficulty in determining the food of these animals. At the present day most of the Blattidæ inhabit warm climates.

Of the three *grasshoppers* of Schambelen (*Gomphocerites Bucklandi*, Pl. VII. figs. 2, 3, *Acridiites deperditus*, Heer, fig. 4, and *A. liasinus*, Heer) only the hind legs and fragments of the wings have been found; but these show that they belonged to the Acridites. The arrangement of the veins of the upper and lower wings is similar to that of existing species.

The Schambelen *earwig*, on the contrary, differed much from all living forms, and constitutes an extinct genus (*Baseopsis forficulina*, Heer, Pl. VII. fig. 5). It differs from existing species in the form of the thorax, and especially in the structure of the head; the eyes are placed at the base of the head, which is the largest part of that organ, and is narrowed to the front, where it is furnished with a short broad lip. Whether the abdomen terminated, as in recent earwigs, in a pair of forceps, cannot now be ascertained. In the form of the head and thorax this insect resembles the anthophagous beetles (Coleoptera), and thus it seems to form a remarkable transition between the Orthoptera and the Coleoptera, which is wanting in the existing fauna.

B. *Neuroptera.*

The Termites, or white ants, are the terror of the torrid zones. They live together in communities of many thousands, consisting of larvæ, pupæ, and neuter individuals; the latter characterized by their large mandibles, and called *soldiers*. The pupæ are as active as the larvæ, and become transformed into sexual animals furnished with wings, which issue from the nest in great numbers after sunset. While swarms of them are about, pairing takes place, and subsequently the males die; but individual females are conveyed back into the nest, when they take the appearance of shapeless sacks, which, in some species, are said to contain as many as 80,000 eggs. They agree with the cockroaches in their nocturnal habits, working only in the dark, and feeding upon vegetable matters of all sorts. In their structure also they have much in common with the cockroaches, but nothing with the true ants. The parts of the mouth are like those of the Blattidæ; the wings are laid in the same way over the abdomen, and exhibit a similar arrangement of the principal veins. The legs are organized for running; and the abdomen is flat and soft, and furnished with two appendages at the extremity. Like the cockroaches, the termites appear in the Carboniferous period; and it is very curious that the wings of some carboniferous Blattidæ have a fine reticulated arrangement of secondary veins, like that of the wings of carboniferous termites, which disappears in the Blattidæ of the Lias. Thus these two oldest types of insects were far more closely related in their earliest period of existence than they are at the present day.

At Schambelen six species of termites have been discovered. They agree with the existing species in the general arrangement of the veins of their wings, but differ from them in many other respects; so that they must be regarded as forming peculiar extinct genera, of which Prof. Heer distinguishes two. In one of these (*Clathrotermes signatus*, Heer, Pl. VII. fig. 8) the costal area of the wing is divided by delicate transverse nervures into a series of quadrangular cells, and the wings are spotted with black; in the other (*Calotermes*) these transverse nervures are wanting, but the wings are spotted with black in one species (*C. maculatus*, Heer, Pl. VII. fig. 7), or they have a dark costal area (as in *C. plagiatus*, Heer, Pl. VII. fig. 6). These dark spots and bands are peculiar to the Termites of the Lias; for all the living species have colourless wings. The Liassic species, like those of the present day, differ much in size; the smallest (*Calotermes troglodytes*, Heer) has wings only 3½ lines long; in the largest (*C. obtectus*, Heer) they attain a length of 9 lines.

The most ancient of the dragonflies (Libellulidæ) occurs at Schambelen; it is the *Æschna Hageni*, Heer (Pl. VII. fig. 9), which is larger than any living species. In the arrangement of the veins of the wing, so far as this is preserved, it agrees with existing forms, and consequently the generic type *Æschna* extends back to the period of the Lias. The Schambelen species is very like one from the English Lias (*Æschna liasina*, Strickl.); but it is considerably larger, and in this respect resembles the gigantic dragonfly of the Upper Jurassic series.

C. *Coleoptera.*

Beetles are remarkable in the existing fauna of Switzerland by their astonishing variety of forms; and their species are more numerous than those of any other order of insects. Still more strikingly is this the case with coleopterous insects of the Swiss Lias, which are represented by three times as many species as all the other orders put together. These species belong to the following sixteen families:—

	Species.
GEODEPHAGA.	
Carabidæ	11
GYRINIDÆ	6
CLAVICORNES.	
Nitidulidæ	7
Peltidæ	4
Cryptophagidæ	2
Lathridiadæ	1
Mycetophagidæ	1
Byrrhidæ	5
PALPICORNES.	
Hydrophilidæ	15
LAMELLICORNES.	
Aphodiidæ	1
STERNOXI.	
Buprestidæ	33
Elateridæ	10
MALACODERMES.	
Telephoridæ	3
STENELYTRA.	
Cistelidæ	1
Rhynchophora	7
CHRYSOMELINÆ	3
Doubtful forms	6

Whole orders are wanting in the Swiss Lias, which does not possess the Longicornes, the Ladybirds (*Coccinellæ*), the Xylophagi, Melasomata, or the Brachelytra, now so numerous; and other sections are but scantily represented, such as the Lamellicornes and Chrysomelinæ, which live in such great numbers in the Swiss meadows and woods. The Rhynchophora include the greatest number of species in the Tertiary fauna, as well as in that of the present day; in the Lias they only occupy the fifth place. They live chiefly on seeds and fruits, which at that time were not plentiful.

If we arrange these animals according to the mode of life of their nearest living allies, they will be thus grouped:—

1. *Wood-beetles* (Coleoptera living on wood), which constitute nearly half the species, and indicate that the land was in their time covered with forests. By far the most numerous family is that of the Buprestidæ, which also includes species of the largest size. This family is numerously represented in the Lias of England, and in all subsequent formations from which insects are obtained. Wood-beetles of the Liassic periods of the earth's history are chiefly of this type, which has but few representatives at present in Switzerland, and does not take a prominent place among the insects of the torrid zone, its native country. This predominance of the Buprestidæ is one of the most characteristic features of the insect-faunas of the Lias, as well as of other primæval epochs of the world.

Among the thirty-three species from Schambelen Professor Heer distinguishes seven generic types, of which *Euchroma* and *Melanophila* still exist, whilst the others (*Glaphyroptera, Micranthaxia, Buprestites,* and *Chrysobothrites*) are extinct. The *Euchroma* (*E. liasina,* Heer, Pl. VII. fig. 10) resembles the Brazilian *Euchroma gigantea,* whilst the *Melanophilæ* (*M. sculptilis,* Heer, Pl. VII. fig. 18, and *M. costata,* Heer, Pl. VII. fig. 19) recall to the remembrance species living on the Swiss Conifers. *Glaphyroptera* includes the greatest number of species (sixteen), and is characterized by its flat and smooth elytra. The *Melanophilæ* have the elytra roughly granulated and partly traversed by longitudinal ridges. Of the *Glaphyropteræ* some have very large elytra, with a broad distinct margin, like the species of *Polybothris* from Madagascar (such as *G. insignis,* Heer, Pl. VII. fig. 13, and *G. spectabilis,* Heer); others, such as *G. Gehreti,* resemble the genus *Chrysobothris* in the strongly projecting hinder angle of the thorax; and others again, such as *G. brevicollis,* Heer (Pl. VII. fig. 15), remind us, by their short stout form, rather of the genera *Trachys* and *Anthaxia.*

Still more nearly related to the latter are some small species with shagreened elytra (*Micranthaxia bella*, Pl. VII. fig. 17, and *M. rediviva*, Heer, Pl. VII. fig. 16), which were abundant and probably lived in the pine-forest. The genus *Buprestites* includes species of considerable size; one of them (*B. Lyellii*, Heer, Pl. VII. fig. 11) is distinguished by its sharply striated elytra.

Most of the Buprestidæ at Schambelen have shining black elytra; but it is very improbable that this was their colour during life, although Prof. Heer cannot ascertain whether they were adorned with metallic colours like the majority of their living relatives.

The nearest relatives of the Buprestidæ are the Elateridæ (Skipjacks), well known by their power of throwing themselves high into the air when they are laid upon their backs. Of these insects at least ten species lived upon the Schambelen Lias island. That they had great leaping-power is shown by the strong pectoral spine possessed by one of the species (*Megacentrus tristis*, Heer, Pl. VII. fig. 22). The most abundant species, *Elaterites vetustus*, Brodie (Pl. VII. fig. 21), is characterized by the pale brown or yellow colour of the elytra, which were probably, during life, of a yellow or red colour, as in a similar species living upon Coniferæ (*Ampedus sanguineus*, Fab.).

The Buprestidæ and Elateridæ lived beneath the bark and in the wood of trees only during their larval state; when mature, like the living species of their families, they played in the sun on the trunks and branches. The Peltidæ, on the contrary, rarely quited their habitation beneath the bark. The Swiss Lias island contained a very singular, nearly circular insect of this family (*Cycloderma deplanatum*, Heer, Pl. VIII. fig. 4), which, from its flattened form, could push its way through very narrow fissures into the bark of trees. In the structure of the head and thorax it agreed with *Peltis*.

2. *Fungus-beetles.*—No fungi have yet been found at Schambelen; but the presence of several genera of beetles indicates their existence there. Professor Heer knows seven species, all exceedingly minute, but which, nevertheless, are admirably preserved. The species of *Strongylites* (*S. stygius*, Pl. VII. fig. 23, *S. morio*, Pl. VII. fig. 24, and *S. lævigatus*, Heer) are pretty

insects, with smooth or very finely punctate elytra; in the *Bellingeræ* (Pl. VIII. figs. 5, 6) the elytra are traversed by fine striæ. *Latridiites Schaumii* (Pl. VIII. fig. 1), with its little black eyes and its large projecting clypeus, is preserved.

3. The *Pill-beetles* (Byrrhidæ) live upon mosses; four species from Schambelen belong to this group. Three species (*Byrrhidium arcuatum*, Pl. VIII. fig. 9, *B. morio*, Pl. VIII. fig. 10, and *B. troglodytes*, Heer) are among the most abundant insects at Schambelen, and lead Prof. Heer to suppose that the ground and the trunks of the trees were more or less covered with mosses, although no remains of these plants have been preserved.

4. That the *leaf-eating beetles* were not wanting is shown by two species of the family *Chrysomelidæ* (*Eumolpites liberatus*, Pl. VIII. fig. 14, and *Chrysomelites prodromus*, Heer, Pl. VIII. fig. 13), and by a pretty little *Cistelid* (*Cistelites insignis*, Pl. VIII. fig. 11); but it is difficult to say what leaves they had to feed upon. Most of the living species of these families feed on the leaves of herbaceous plants and deciduous trees; and some live on reeds and conifers; so that the *Bambusiæ*, *Araucariæ*, and *Thuites* of the Swiss Lias island may have served them for food. A small Rhynchophorous beetle (*Sitonites melanarius*, Pl. VIII. fig. 16) probably lived in the coniferous forest, like its nearest living allies (the *Sitonæ*). Whether the other six Rhynchophora of Schambelen fed on leaves, flowers, or fruits cannot be decided.

5. That the *flowers* of that time were frequented by small beetles is shown by some pretty species, whose living representatives often occur in great quantities among flowers. These are *Petrorophus truncatus* (Pl. VIII. fig. 12), like the *Cercus*; *Trixagites floralis* (Pl. VIII. fig. 8), resembling *Throscus*; and *Nitidulites argoviensis* (Pl. VIII. fig. 3).

6. One of the most remarkable insects at Schambelen is a small *coprophagous* beetle (*Aphodiites protogæus*, Heer, Pl. VIII. fig. 15), so closely resembling the *Aphodii* which now live on the excrements of cattle, that one would almost suspect that Switzerland had at that time possessed Mammalia. In fact, the presence of a mammal has been detected in Wirtemberg, and in England, in a still older formation (the uppermost Trias);

but this was a very small animal, and its excrements could hardly have served for the food of an *Aphodius*. Some insects of this group, it must be remembered, live upon rotten wood and decaying vegetable substances.

7. All the preceding insects lived upon plants or their débris; but carnivorous insects were not wanting at that time. Of the beetles we have twenty-nine carnivorous species. The Telephoridæ sought their prey on flowers and leaves, the Carabidæ on the ground. The latter were almost all small insects (*Carabites bellus*, Pl. VIII. fig. 22, *C. harpalinus*, and *Thurmannia punctulata*, Pl. VIII. fig. 17), corresponding with the plant-devouring insects, which served them for food.

8. The *Water-beetles* form an essential element of the insect-fauna at Schambelen; Prof. Heer has twenty species of water-beetles, some of which were plentiful. The *Gyrinidæ* are pretty little beetles, one species of which (*Gyrinus atavus*, Pl. VIII. fig. 18) agrees in character with the Swiss existing forms, whilst four other species (such as *Gyrinites troglodytes*, Pl. VIII. fig. 19, *G. minimus*, fig. 21, and *G. antiquus*, fig. 20) are distinguished by the absence of the scutellum and by the eyes reaching the margin of the head. These Liassic Gyrinidæ are remarkable for their small size. The *Hydrophilidæ* are more abundant; some of them (*Hydrophilites acherontis*, Pl. VIII. fig. 25, and *H. stygius*, fig. 24) are of considerable size; others (such as *Hydrobiites veteranus*, Pl. VIII. fig. 23) are very small. *Wollastonites ovalis* (Pl. VIII. fig. 26), on the contrary, is very rare; it is a peculiar little beetle, probably belonging to the Spercheidæ, which live on aquatic plants in stagnant water.

D. *Hymenoptera.*

This great order, including the well-known Bees, Wasps, and Ants, of which thousands of species are now scattered over the face of the earth, makes its first appearance in the Lias with a single species, *Palæomyrmex prodromus*, Heer (Pl. VIII. fig. 31, enlarged). Only the wing here figured has yet been found; in the arrangement of the veins it shows some resemblance to the Ants, but differs from them in certain essential points; and even the order to which it should be referred is doubtful.

E. *Rhynchota or Hemiptera.*

The family of Bugs is of great antiquity; eight species belonging to it occur at Schambelen. They belong to the group *Coreodea.* Some species (such as *Protocoris insignis,* Pl. VIII. fig. 28, *P. ovalis,* and *Cyclocoris pinguis,* Pl. VIII. fig. 27) are almost perfectly preserved; of others Professor Heer has only the wings. These insects were probably carnivorous, feeding on the blood of the other insects, which they sucked out with their rostrum. Of the little Cicadellinæ three species are found at Schambelen—as well as the *Cercopidium morio* (Pl. VIII. fig. 30) and *C. minutum* (fig. 29), which lived on the juices of plants.

General Conclusions.

1. This rich insect-fauna shows that the land must have been of considerable extent, so that there was more than merely a little island in the Liassic sea. The aquatic insects (Dragonflies and Water-beetles) especially afford evidence of this fact; they are so numerous that they imply the presence of a river or large lake. It is also known that all small oceanic islands, such as the Canaries, Madeira, and the Azores, possess very few aquatic animals, their streams being small and periodically dried up, so that the means of existence are constantly wanting to freshwater animals.

At the period of the Keuper, the continent of the Black Forest (the German Odinland) extended, as we have seen (p. 48), to Passwang and Staffelegg. Whether it reached Schambelen is not ascertained; but the Keuper of that place has been shown (p. 57) to have been probably formed in brackish water, proving the existence of a shore, and the oldest Liassic deposits owe their origin to a shore. The Liassic marls of Schambelen form the south coast of the continent, which may be traced to Staffelegg near Aarau. There, on the northern side, near the opening of the Aar valley, in west Frickthal, above the high road, Professor Heer found in the Lias shale two species of insects, the *Nitidulites argoviensis* (Pl. VIII. fig. 2) and *Glaphyroptera,* one of which has been discovered at Schambelen. There is also immediately above the Lias shale in this locality, as at Schambelen, a limestone bed containing the *Gryphæa arcuata* and the *Ammonites Bucklandi*, proving that the rocks in both places were identical.

Very little evidence can be given of the form, at the Liassic period, of the alpine island, mentioned (p. 3) in the first chapter. A species of Horsetail (*Equisetum*) has been discovered in the Lias, near Tarasp in the Lower Engadine, probably identical with one from Schambelen (*E. liasinum*, Pl. IV. fig. 11); and some land-plants, to be mentioned by-and-by, have been found in the Stockhorn chain, as well as near Bex in the uppermost strata of the Lias.

2. The Lias island at Schambelen must have produced fungi and mosses, the remains of which have been sought for in vain. But the insects do not prove that Dicotyledonous trees and plants existed at Schambelen. We know very little about the relations of insects to the Cycads, and, in general, the mode of life of tropical insects is entirely unknown to us. The starchy trunks of the Cycads probably furnished food not only to the termites and cockroaches, but also to the larvæ of many Buprestidæ, whilst we have the proper food-plants of other insects (namely the five species of *Melanophila*, the Elateridæ, and the Sitonites) in the Conifers of the Schambelen (*Araucarites peregrinus* and *Thuites fallax*). The *Chrysomelites prodromus* probably lived on the *Bambusium liasinum*, like the *Chrysomela graminis* which is met with on reeds. Liassic rocks do not contain the Melolonthidæ and other families of Lamellicorn beetles, which live in forests of deciduous trees; nor do the strata of Schambelen comprise thousands of other forms of insects which now derive their nourishment from Dicotyledonous trees and plants.

3. With respect to the size of insects at Schambelen (see the figures in Pls. VII. & VIII.), there are some large species (such as the dragonfly and *Euchroma*); but most of the insects are small, some even smaller than their smallest living relatives, as is also the case with the insects of the English Lias. When the conditions of climate and produce are favourable to a luxuriant growth of plants and insects, the largest forms of the insect class are developed, as in tropical America and Asia; but side by side with these insect giants, thousands of minute,

dwarfish species are to be found. Thus we can infer, from the general smallness of the Liassic insects, only that insect-life was not then so luxuriant, and could not produce such large forms as the tropical world of the present day, because the dicotyledonous trees, full of leaves, on which insects chiefly feed, were still wanting. But if we glance at the numerical proportions of the families, we find evidence of a warm climate. We may refer especially to the Buprestidæ, which are so numerously represented, and also to the termites and cockroaches; of the first, eight tropical forms occur; and the cockroaches much more resemble similar insects in the torrid zone than in Switzerland at the present day. Similarly we find that Cycads now live only in the warm and torrid zones, and that a hot climate suits thick reeds and the ferns with a polygonal reticulation. The *Araucariæ* certainly extend from the warm into the temperate zone; and the *Thuyæ* can live in northern latitudes; but as both these forms of Conifers advance far towards the south, they do not disprove the warmth of the ancient climate at Schambelen.

That the sea, as well as the air, had a higher temperature than prevails at present in the latitude of Switzerland, is shown by the Ammonites, whose nearest allies, the *Nautili,* live in the Indian Ocean, and by the Pentacrinites, which are only found on the shores of the West-Indian Islands. The absence of coral-reefs in the Lias seems at the first glance remarkable; but it must be remembered that this is also the case in those parts of the tropics where a river runs into the sea, or where much mud is deposited, mud being fatal to the polypes. There is no trace of coral in the dark-coloured marls of the Lias.

4. The Lias of the Black Forest and generally of the south of Germany contains no land-plants; but a similar shore formation is seen near Halberstadt and Quedlimburg, as well as in England (especially in Gloucestershire, Warwickshire, Somersetshire, and Dorsetshire). Plants have been found in these places, and insects in England; but no traces of deciduous trees have been discovered. The forests consisted of cycads and conifers, and the herbage of numerous ferns, among which Professor Heer finds some of the same species as on the Swiss Liassic island (such as *Phlebopteris polypodioïdes* and *Camptopteris Nilssoni*). The Swiss *Araucarites peregrinus* also occurs

in the Lias of England. In general the flora of the Lias has the same character as that of the Trias, the chief distinction being that, at least in Switzerland, the large arborescent Horsetails (*Equiseta*) are reduced to an herbaceous form, and the Calamites become quite subordinate and disappear entirely in this period.

From England 56 species of insects in the Lias are now known, of which 7 belong to the Orthoptera, 12 to the Neuroptera, 29 to the Coleoptera, 6 to the Rhynchota, and 2 winged species which are doubtful. Although only a few species (*Elaterites vetustus*, Brod., *Hydrobiites veteranus*, and perhaps *Gomphocerites Bucklandi*, Brod., *Bellingera ovalis*, and *Glaphyroptera gracilis*) have been found both in Switzerland and England, the insect-fauna of both countries had the same general character in the Liassic period. The beetles constitute the richest order; then follow the Neuroptera, Orthoptera, and Rhynchota. Lepidoptera and Hymenoptera are wanting, and the traces of Diptera are very uncertain. Among the beetles, the Buprestidæ predominate; and among the water-beetles are numerous small Hydrophilidæ. In England, as well as in Switzerland, little *Cicadellæ* jumped about in the bushes, large dragonflies swept through the air, cockroaches and termites sought their food in the forests, and lively companies of *Gyrini* played on the surface of the water. Grasshoppers then, with their songs, were probably the only creatures that broke the silence of the primæval forests.

From the common character of insect-life in both countries, we may infer that probably a similar climate prevailed in the Liassic period both in Switzerland and England. Even the materials of which the older Liassic rocks are constructed in many parts of England are exactly the same as in Switzerland.

Generalizing our views of Liassic formations, we may see in imagination the hills crowned with rigid, palm-like cycads and dark conifers, under the shadow of which grow ferns and fungi. Through the low grounds meander rivers, fringed with tall reeds and herbaceous horsetails (*Equiseta*); great dragonflies rise above the water, and sweep through the reeds of the river-banks; whilst shining Buprestidæ, slender Elateridæ, and pretty little

Nitidulidæ fly about and sun themselves on the leaves and flowers of the Cycads.

This picture is brighter and pleasanter than that of the Carboniferous period. The superabundant vapour of the atmosphere has diminished, and the excess of carbonic acid in it has been partially consumed by the vegetation; the carbon has been taken up in vegetables, and deposited in the earth as coal, to be a blessing to distant ages; the air has thus become lighter, and more transparent, and the sun has already exerted more freely its vivifying influence.

The marls of the Lias formation containing insects and land-plants at Schambelen are but of small thickness; in the uppermost marly beds these fossils are no longer found; above the marl occurs a stratum, 10 feet thick, of limestone, in which no trace of land organisms can be detected. This limestone comprises in its lower portion a bed, about 4 inches thick, containing numerous branched cylindrical bodies (*Cylindrites lumbricalis*, Kurr), which probably originated from marine plants; in a second and still lower bed, about 12 inches thick, occur Ammonites (*A. Bucklandi*), Brachiopods (*Rhynchonella variabilis*), *Pleurotomariæ* (*P. similis*), and Belemnites (*B. acutus*); in a third and hard siliceous bed, fossils are wanting; whilst, in a fourth, many marine animals occur, such as *Gryphææ*, Ammonites (*A. planicosta*, *A. armatus*), Brachiopods (*Rhynchonella oxynoti*), and Pentacrinites.

The most abundant fossil is the *Gryphæa obliqua* (fig. 55), which elsewhere appears only in a higher bed of the Lias (the "Betakalk" of Quenstedt), and leaves the corresponding lower Lias deposit to another nearly allied species (*Gryphæa arquata*). The *Gryphææ* have two very unequal valves, one of which has a long spirally incurved beak, whilst the other (smaller) one is flat or even concave. Of the Ammonites, *A. Bucklandi* is distinguished by its size, some specimens attaining to a foot in diameter.

In this limestone deposit of Schambelen the Belemnites (*B. acutus*, figs. 56, 57) first make their appearance in great abundance. They are conical bodies, often drawn out into a fine point in front, and are distributed throughout the whole Jurassic series, and in some places occur in thousands. They have consequently been long known to the common people, who call them Devil's fingers, cat-stones, and thunderbolts, and ascribe to them supernatural powers; and thus they form an article of commerce, like the Ammonites of the Himalayas. A careful examination of Belemnites has long since shown that they correspond with the so-called "bone" of the cuttlefish, and therefore must have been derived from similar animals.

Fig. 55.

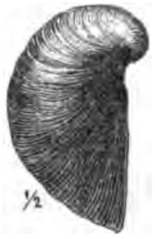


Fig. 56.

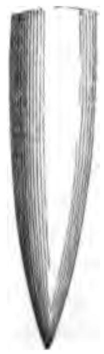


Fig. 58.

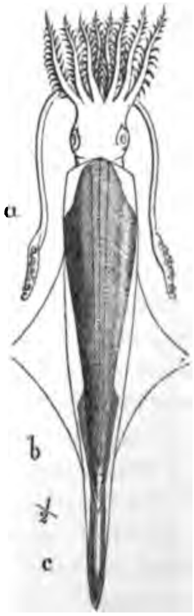


Fig. 57.

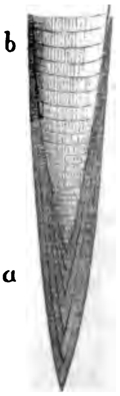


Fig. 55. *Gryphæa obliqua*, from the gryphite limestone of the Schambelen.
Fig. 56. *Belemnites acutus*, Mill.
Fig. 57. The same, longitudinal section.
Fig. 58. A restored Belemnite, as it probably appeared when alive.

In the perfect Belemnite three parts may be distinguished. First, a thin horny cornet (fig. 58, *a*), closed at the bottom but open in front, and produced in the dorsal part into a shovel-like piece, the margins of which are not united along the ventral side; secondly, a calcareous cone (the *alveolus* or *phragmocone*) (fig. 58, *b*) placed at the point of the cornet and divided into a number of chambers by thin transverse partitions or diaphragms, each of which has a tubular appendage on the ventral side, usually reaching to the next, so as to produce a tube or *siphon* traversing the cone; thirdly, a calcareous sheath (or *guard*) surrounding the phragmocone (fig. 58, *c*), composed of numerous radiately fibrous layers, and forming the conical-pointed part of the Belemnite. This guard is hollowed out at the base; and in its cavity the phragmocone is inserted. The cornet is very rarely preserved; so that only the phragmocone is found with the guard, or even the latter alone. The whole apparatus, like the bone of the cuttlefish, was enclosed by soft parts, which, however, have not been preserved, and therefore we can only form an approximate notion of these animals from their analogy with the living cuttlefish, *Sepia* (fig. 58). This remarkable type is first indicated in the Trias by a few indistinct traces; but it is only in the *gryphite limestone* that individual specimens are met with which can be determined.

The gryphite limestone, which occurs also on the Staffelegg, in the Frickthal, near Laufenburg, and in various places in the Cantons of Basle and Soleure, is immediately followed at Schambelen by a yellow sandy limestone and a light-grey sandy marl. Above this the soil is chiefly covered with vegetation; but 125 feet higher it again comes to light, and forms the marl-pits above the road near Müllingen. Here the marl is of the same nature as in the lower pit; but there are no remains in it either of insects or terrestrial plants. This marl does not belong to the Lias, but to the oldest Brown Jura, the "*Opalinus*-clay," which will be described in the next chapter. The rocks between the upper and lower grits represent the higher beds of the Lias, the Upper Lias (or Toarcian stage). They are true marine formations, in which *Ammonites communis*, *Estheria Bronnii*, *Chondrites bollensis elongatus*, and some Polythalamia have been found at Schambelen.

The Upper Lias, however, and the beds between it and the Lower Lias, the Middle Lias, are much better developed in other districts, in the Cantons of Aargau, Basle, and Soleure. M. C. Mösch has observed more than seventy species of marine animals in the Middle Lias of Aargau (at the Kirchacker of Ittenthal, in the Rebberg north of Frick, in the Zeinlematt, and near Gipf). Here and there the soft dark marls alternate with hard, slaty, limestone beds, which, when broken, diffuse a strong odour of bitumen and ammonia. These split into very thin plates, and are rich in fossils, among which there are numerous Ammonites and Belemnites, oysters, and *Estheriæ*. With these animals M. Mösch has discovered fishes (*Lepidotus gigas* and *Leptolepis Bronnii*) in these beds in Aargau, and also bones of the great *Ichthyosaurus platyodon*, Conyb.* In some places the rocks of the Upper Lias are filled with the remains of a marine alga (*Chondrites bollensis*, Pl. IV. fig. 20), as between Gausingen and Büron and in the Posidonia-shales of Betznau; these form light-coloured, thickly branched tufts on the dark stone †. With it there occurs, at Betznau, a curious plant, *Fucoides Mœschii*, Heer (Pl. IV. fig. 23, *b*, one half nat. size), which had a long thick stem, terminating at one end in an oval, and at the other in a kidney-shaped body, the latter probably a great air-bladder. This may be compared to *Fucus nodosus*, of which the stem is inflated here and there into large air-bladders; and, in fact, in some of the fossils the stem is continued beyond this dilated portion (Pl. IV. fig. 23).

We have seen in the first chapter (pp. 3 & 35) that the Swiss Alps formed an island composed of crystalline masses and anthracitic shales. In the district of the Stockhorn, and in the neighbourhood of Aigle and Bex, there must have been dry land at the time of the Upper Trias, in the form either of small islands or of peninsulas and promontories, extending from the alpine land. In these places several land-plants have been found. At the summit of the Hochmad, halfway up the Blumenstein, three interesting species of land-plants have been discovered—a Cycad (*Zamites gracilis*, Kurr, Pl. V. fig. 1) and two Conifers (*Widdringtonites liasicus*, Kurr, Pl. V. fig. 4, and *Thuites fallax*, Heer, figs. 2, 3)—one of which is also known to Professor Heer at Schambelen (p. 80). The Cycad had leaves a foot long, but only half an inch broad; their rigid, flat pinnæ, traversed by numerous longitudinal veins, and obtusely rounded at the end, were attached to the upperside of the rhachis of the leaf, which they partly covered. The two Conifers probably resembled the Swiss *Arbor vitæ* in aspect. In the Upper Lias of the neighbourhood of Bex, a fern (*Sagenopteris Charpentieri*, Heer, Pl. V. fig. 5) has been found, the venation of which is very finely reticulated. No doubt several such pinnæ as that represented in the Plate were united to form a palmate frond.

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* At Teys à chaux (Moléson, Canton of Friburg) an *Ichthyosaurus tenuirostris*, Con., 8 feet in length, has been found.

† We find here two forms of this seaweed—one with branches closer together and somewhat narrowed at the base (*Chondrites bollensis cæspitosus*, Kurr.), and the other with the ramifications longer and more separated (*C. bollensis elongatus*, Kurr). Fine specimens of the first form have been received from the Randen (Pl. IV. fig. 20); the second form is obtained from the Lechthal and Bernhardsthal in Vorarlberg. Prof. Heer has also received this *Chondrites* from the Col de Madeleine and the Col des Encombres in Savoy, and from the red Ammonite-limestone of the Alp Baldovana near Mendrisio. It is therefore very abundant in the Upper Lias. The *Chondrites filiformis*, Fisch., found near Bex (Pl. IV. fig. 22), has rigid, filiform branches (only $\frac{1}{10}$ line in breadth), which stand far apart; and the *Chondrites divaricatus* has thin and very delicate branches, of nearly equal length, more approximated and more dilated, and separating at less acute angles.

The *Zamites* and *Widdringtonites* of Blumenstein have been found with an *Araucarites* in the Upper Lias of Boll in Wirtemberg, a coast-region which has become celebrated on account of the remarkable fauna discovered in it. It was here that the gigantic Ichthyosaurs which adorn the museum at Stutgard were found; and here are met with long-beaked gavials and flying saurians, as well as cuttlefishes with their ink-bag still preserved, and many fishes with shining scales.

Near Bex, and in the chain of the Stockhorn (at Langeneckgrath and Blumensteinallmeind), numerous marine Liassic animals occur*, showing plainly that the sea extended into that region. Several marine algæ are found there, such as *Chondrites bollensis, filiformis*, Fisch., and *divaricatus*, Fisch., with numerous Ammonites (66 species), Belemnites, *Inocerami, Limæ*, and Brachiopods. In the interior of the Swiss Alps only a few traces of deposits of the Liassic period are known to Professor Heer.

The land-plants of the alpine island have been probably destroyed, without leaving any traces behind them; and the deposits of the sea which washed this large piece of ground have probably been in part carried away by the waves and in part covered up by newer formations.

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* M. K. Brunner, in his memoir on the Stockhorn (Denkschr. der schweiz. naturforsch. Gesellschaft, Band xv.), cites 119 species of marine Mollusca from the Lias of that chain; of these, 34 belong to the Lower Lias, 53 to the Middle Lias, and 32 to the Upper Lias. The last agree in species and in their state of preservation with Mollusca of the Upper Lias of Swabia.

Proofs exist that the sea formerly advanced northwards into the region of the Swiss limestone Alps, and that fiords, with steep banks, enabled the sea to penetrate to the south into the land. These proofs are furnished by the remains of marine animals found at the Glärnisch and at Magereu (*Cardinia*[*]), as well as by the limestone deposits, with Belemnites, which extend from Lukmanier, across the upper portion of the Livinenthal, as far as Nufenen, and, lastly, by the limestone rocks in the south and the centre of the Grisons. These rocks are now closed in by masses of shales and Grison granites, and only show themselves like small separate islands; but, without doubt, they were formerly united. As fossils are very rarely found in these limestone rocks, it cannot be decided whether the strata were deposited in the Liassic period or after that epoch.

Numerous Belemnites, however, apparently belonging to the Lias are contained in the limestone near Santa Maria, on the Lukmanier, and at Samaden in the Engadine. Professor Théobald has discovered at the Piz Padella, north of St. Moritz, in the Upper Engadine, marine *Algæ*, of which the most abundant species agrees with similar *Algæ* from the Lias, being the *Chon-*

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[*] Escher de la Linth has found, to the south-east of Magereu (on the eastern slope of the Malabitz), a band of dark limestone with reddish-yellow spots, containing *Cardinia hybrida*, Sow., *C. concinna*, Sow., *C. Listeri*, Sow., *C. Deshayesi*, Terq., *C. De Soudini*, Terq., and *Plicatula hettangensis*, Terq. These fossils show that this deposit belongs to the Lower Lias (*Sinemurien*). Higher up, in the environs of Magereu and Spitzweilen, are black granular limestones which contain remains of *Pentacrini*; and near Betschwanden are *Pecten Hehlii* and *æqualis*, D'Orb. On the slopes above Ruti, besides the two scallops just mentioned, *Pecten textorius*, Goldf., and *Ammonites Conybeari* are met with; these limestones would therefore belong to the zone of *Ammonites Bucklandi*. The limestone between Mols and Molseralpweg has furnished *Spirifer pinguis*, *Terebratula cor*, Lam., *Pecten Hehlii* and *P. textorius*, *Pinna Hartmanni*, and *Belemnites acutus*. It is to the Upper and Middle Lias that must be referred the numerous arenaceous and quartzose limestones forming the mountains of Magereu, Gulderstock, and the Braunwalderalp, near Klausen. They contain Belemnites and, at the Oberblegialp, *Terebratula numismalis*. See J. Bachmann, on the Jurassic formation in the Canton of Glarus, 'Berner Mittheilungen,' pp. 144 & 549.

drites filiformis (Pl. IV. fig. 22) from the Piz Padella, which was widely spread in the Liassic period, and which Professor Escher de la Linth has also obtained from the Lias of the Vorarlberg. *Chondrites Padellæ,* Heer (Pl. IV. fig. 21), a singularly graceful plant, fine, like a hair, and with very stiff branches, has hitherto been found only at the Piz Padella. In the Prättigau the Lias appears at the bottom of the valley above Ganey, where Professor Théobald discovered a Liassic Ammonite.

The Lias of the Engadine and Vorarlberg has the same character as that of Bavaria and Austria; whilst the Lias of the Western Alps and the Jura agrees with that of Swabia and France. The latter consists of black limestones and shales, the former of an alternation of red and grey limestones. Eastern Switzerland must consequently have formed the boundary between the Lias seas of the south-east and the west of Europe, although the coast-lines cannot now be exactly made out.

The difference which exists between the Lias deposits of the two seas is probably due to the different nature of the soil which furnished the sediments.

The Triassic formations of Eastern Europe were chiefly deposited in a deep sea, whilst those of Western Europe were formed partly in freshwater lakes and partly in a shallow sea and brackish water. The former, therefore, are principally hard limestones, the latter soft marls and sandstones, which furnished the materials for the marine deposits of the Liassic period, and may have caused their dark colour and marly nature.

We have already mentioned that the Lias marls are employed for manuring the fields. In many places they are dug out in great quantities and exported to long distances. This employment of marl is very ancient; we read, in Pliny, that in Gaul and Britain the fields were manured for eighty years with "this fat of the earth." The Lias generally furnishes a very fertile soil. It forms the low hills and valley-bottoms clothed with luxuriant vegetation which accompany the chain of the Jura through the Cantons of Aargau and Soleure. Even in the deserts of the dolomitic regions we find luxuriant green meadows wherever the Liassic beds have spread over the dolomite. The Lias marls contain petroleum, probably derived from the fat of animals buried in those strata, which has combined with mineral substances. In Swabia petroleum occurs in the marls of the Upper Lias in such quantities that it is obtained on a large scale near Reutlingen, and furnishes an excellent lamp-oil. According to Quenstedt's calculation, a square mile of the bituminous shale at the foot of the Swabian Alps contains at least 200,000,000 hundredweights of this oil; and he justly remarks upon the great results produced by nature in this locality by apparently small means.

CHAPTER IV.

JURASSIC SEA.

To enjoy the magnificent spectacle which the sea presents, the inhabitant of Switzerland must undertake a long journey. He will see a world of plants and animals on the shores of the ocean; and by studying the remains which the agitated sea casts up, he will become acquainted with living forms belonging to marine waters.

The Swiss may, however, with less trouble, make himself master of ancient oceanic natural history; he resides in the midst of a vast marine bay, from which the water has flowed off and has left the land dry below it. He cannot stretch his gaze, in the low lands of Switzerland, over tracts of sea-water; but the upheaval of the bed of the ancient ocean, in his own country, has laid bare before him treasures formerly concealed beneath deep-sea waves.

In Switzerland, extensive coral-reefs are found, forming great rocky walls, once inhabited by myriads of little animals, which busied themselves in building these limestone rocks. Sometimes we meet with the remains of great numbers of marine animals lying together in such a manner as to show that the animals themselves must have lived on the spot, and been overwhelmed and imbedded in their rocky tomb by some sudden catastrophe; at other times we observe masses of shells and radiate animals disposed just as they are now to be found under the influence of stormy waves, when thousands of the inhabitants of the sea are thrown on the beach. If it is a pleasure to wander along the coast picking up the productions of the sea which have been cast ashore, we find an interest, blended with surprise, in discovering in Swiss mountains the inhabitants of sea-shores belonging to a primæval period.

The collections made by nature during thousands of years are contained in these Swiss deposits, and reveal to us a richer and more varied fauna than any coast can now offer. Such marine remains carry us back to a time when an immense sea extended over a great part of Europe, and in Switzerland only a few islands and coral-reefs rose above its surface. We seem to look over this widespread watery surface, to see how the blue waves broke into white foam in rushing against reefs of rocks; we seem to hear the thunder of the surf as the waves dashed against the land, and the gentle murmur of the tide as the water retired from the shore.

The marine animals enclosed in the Swiss Jurassic rocks not only tell us that Switzerland was covered by the sea at the time of their deposition, but they give us information as to the nature of the sea-bottom, and thus enable us to glance into the most secret depths of the Jurassic sea. We learn that there are regions of the sea adorned with an abundance of organized beings, and others which are completely desert.

Some marine animals always remain in definite localities, whilst others undertake great migrations. Some remain constantly in one place and live at the bottom of the sea, or rise from it only for a time and for a short distance; others quit their birthplace and trasverse the vast deserts of the ocean, either singly or in great troups. These "pirates," as they have been called, may be divided into two groups: some of them reside by preference in certain localities where they play about among the meadows of seaweeds, or conceal themselves in cavities of the rocks, watching for their prey; while others traverse the waves in all directions and often migrate to great distances. The migratory races include the Polycystina, the Tunicata, and most of the Acalephæ, as well as many fishes, such as Mackerel, Tunnies, Swordfishes, Herrings, and Sardines. They are governed in their migrations by the seasons, which also regulate the depths at which many of them reside; but the voracious Sharks and the Dolphins traverse all depths. The residentiary group also includes many fishes; the Labroidei swim about in the meadows of grasswrack and seaweed; the Barbillons and Sparoidei visit the rocky depths, and with them most of the Cuttlefishes are associated. Of marine plants, the species of *Sargassum* occur in abundance on the open sea far from all land. They are not attached to the bottom, but float freely in the water, forming widespread meadows of seaweed.

The same laws which govern the plants and animals of existing seas apply also to those of former geological ages. In the Swiss Jura, we find rocks which are filled with the remains of animals, and other rocks of great thickness from which such remains are entirely absent. The former strata would seem to have been formed near the shores or in shallow water, and the latter beds, especially when they consist of a finely granular mass, at great oceanic depths. However, conditions may occur, even on the coasts and in shallow water, which prevent the settlement of plants and animals, such as a violent surf on a shifting sea-bottom consisting of pebbles and sand. In general a more or less favourable position must have the same influence upon the inhabitants of the sea as upon those of the dry land; and thus marine regions are produced which may be compared to countries thickly covered with towns and villages, whilst other regions resemble scattered colonies, isolated dwellings, and oases in great deserts. The boundaries of the distribution of land plants and animals are formed by seas, deserts, and high ranges of mountains, and those of many marine organisms by the great depths of the ocean.

As we approach the sea, the land-flora gradually changes; and the shore of the ocean is adorned with a belt of peculiar strand-plants; and the further we go below high-water mark in search of forms of life, the more do these forms become modified. Rocks and stones on the shore, which are covered with water at flood-tide, are inhabited by animals which either attach themselves like plants to the rocks (such as Cirripedes) or adhere to them very firmly (like Limpets), and thus resist the violence of the waves. Others, like the *Littorinæ,* conceal themselves in the cavities of the rocks, and, closing their shells by means of a hard lid, can bear the absence of water for a long time. Thus these animals lead an amphibious life.

Where the water is rendered brackish by streams and springs flowing in, green Algæ (*Enteromorphæ, Ulvæ,* and *Confervæ*) grow in great abundance, forming a green belt along the shore;

in other places, especially on abrupt walls of limestone, the Nullipores often border the coast for miles; these are white plants with rigid stems and branches, which look like corals. During the ebb-tide, these plants become dry and retain their freshness and vitality whilst exposed for hours to the action of the air and sun. They inhabit the intermediate district lying between the levels of high and low water, which has been called the SHORE ZONE.

A second zone is that of shallow water, extending from low-water mark to a depth of about 100 feet; it is called the SHALLOW-WATER ZONE, and is the chief residence of marine plants and animals. The forms of the shrubs and branched trees of dry land are here seen in miniature; and the plants surprise us with the beauty of their colours. Seaweeds growing on a rocky bottom form widespread meadows and forests, and are of a dark olive-green colour (*Laminariæ* and *Fuci*), whilst the Florideæ are clad in rose-colour and violet. Many are remarkable for their delicate structure, and grow under the mutual shelter afforded by each other, or they twine about larger plants, and cover them as the lichens and mosses of dry land grow over trees. In the upper part of the shallow-water zone dwell the *Delesseriæ*, *Gigartinæ*, *Gelidiæ*, *Plocamiæ*, *Callithamnia*, *Sphærococci*, and *Chondri*; and on sandy and gravelly bottoms, the grasswracks (*Zosteræ*) form their green sward; dense masses of *Cystosira* are met with here and there. This is the dwelling-place of the fine-spined Sea-urchins, of Starfish, and of many Mollusca (such as the species of *Purpura*, *Patula*, *Rissoa*, *Conus*, *Trochus*, *Murex*, *Pinna*, *Astarte*, and *Cardita*, and the Oysters and Scallops, and, in the warmer and tropical seas, of the genera *Melo*, *Mitra*, *Strombus*, *Terebra*, *Triton*, *Ovula*, *Cerithium*, *Donax*, *Mactra*, *Arca*, *Corbula*, &c.). It is also the region of the reef-building Corals, of Madreporidæ and Astræidæ, which play so important a part in the seas of the torrid zone. The Nullipores continue from the shore zone into the shallow-water zone, and are often found in immense quantities near the corals. A great number of worms live in the sponges and in holes and fissures of the rocks. The Lobsters, Shrimps, and other Crustacea select the rocky spots, but only in the upper part of the shallow-water zone. Luminous animals appear occasionally in swarms, illuminating the dark waters like stars. Numerous fishes belonging to the wandering group also occur here. It is remarkable that in general both the plants and the animals of this zone, especially in the tropical ocean, are distinguished for their brilliant colouring.

Descending further we reach the MIDDLE ZONE (from 100 to 300 feet) which is still richly inhabited. In European seas the hydroid polypes (especially the *Sertulariæ* and *Plumulariæ*) are here very abundant, forming elegant miniature trees and shrubs. Bivalve Mollusca, including *Pectens*, form great beds here and there. Sea-Tangs and Florideæ have become scarce; but in the Adriatic, great quantities of Nullipores occur in some places, and occasionally *Cystosiræ* and *Gelidiæ* and green *Codia* and *Valoniæ*.

In the LOWER MIDDLE ZONE (from 300 to 600 feet), the larger seaweeds (Tangs and Florideæ) are wanting. The animals also have become much scarcer and their colours have faded or disappeared. Its chief inhabitants are coralliform Bryozoa, some peculiar Echinoderms (*Cidaris*, *Astrophyton*), Sponges (*Tethya*), and a number of Mollusca (including *Avicula*, *Venus*, *Lima*, *Pecten*, *Turritella*, *Corbula*, *Cardium*, *Nucula*), among which the Brachiopoda are to be especially noticed. Some species of fishes, such as the curious marine cat (*Chimæra monstrosa*), and a few species of *Sebastes* and *Molva*, seem also to prefer these depths. In the Mediterranean, this zone is the dwelling-place of the highly prized Red Coral.

The depths below 600 feet are included in a single zone (the ABYSSAL ZONE). In the Mediterranean no plants are met with below 600 feet, except some microscopic forms, and animal life becomes improverished and finally extinguished*. In the

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* The numerous investigations made by Dr. Lorenz in the Adriatic (see his 'Physical relations in the distribution of Organisms in the Gulf of Quarnero,' Vienna, 1863) have essentially confirmed the results previously obtained by Edward Forbes. Most of the plants and animals of the Adriatic occur in the shore and shallow-water zones; beyond 300 feet there are only a few species. The labours of Lorenz have shown that below 200 feet there is so rapid a diminution in the number of species, that probably at greater depths in the Mediterranean plants and the larger forms of animals disappear. Nevertheless, when the telegraphic cable between Sardinia and Algeria was raised, after lying at depths of 2000 and 3000 metres for two years, there were found attached to it three species of Mollusca (*Ostrea cochlearis*,

Atlantic Ocean, however, the higher forms of animals descend much lower; and this applies equally to the extreme north, to the temperate zone, and to the tropics. Dr. Torell has informed Prof. Heer, that he observed no important diminution in the fauna at great depths off the coast of Greenland. At about 1500 feet he still found 20 Mollusca (among which was the *Terebratella spitzbergiensis*). Between Spitzbergen and the North Cape, in 76° 7′ N. lat., he obtained, from a depth of 1400–1500 fathoms, numerous Polythalamia (*Globigerina, Dentalina, Nonionina,* and *Biloculina*), a crustacean (*Cuma rubicunda,* Lilj.), some *Serpulæ,* and some Mollusca (*Dentalium* and *Bulla*).

On the Norwegian coast, Sars has ascertained the existence of 427 species of animals at 200 and 450 fathoms depth, and of 42 species below 450 fathoms in depth. Carpenter and Thomson have obtained similar results in English waters. The latter even found, at a depth of 2435 fathoms (14,610 feet), a *Dentalium,* a Starfish, one or two Crustacea, several Annelides, and numerous Polythalamia. M'Clintock and Wallich met with living Brittle-stars at 7560 feet. The soundings made by M. de Pourtalès, at 567 fathoms in tropical seas between Florida and the West Indies, furnished a crustacean, a brittlestar, and some Annelides. He also ascertained that in tropical regions there is an abundant fauna between 100 and 300 fathoms in depth. Near the south pole, Dr. Hooker obtained living zoophytes (*Primnoa Rossii, Melitæa australis,* and *Madrepora fissurata*), and some

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Pecten opercularis, var., and *Fusus lamellosus*) and three Corals (*Caryophyllia arcuata, C. electrica,* sp. n., and *Thalassiotrochus telegraphicus,* sp. n.). But unfortunately we do not know the depth of the sea at the precise place where this part of the cable rested. It is remarkable that the number of species of plants (except the Diatomaceæ) decreases much more rapidly than that of animals. The diminution of the species of animals is slower and more constant; animals of large size and high organization descend to comparatively greater depths, and these maintain their characteristic forms. It would seem therefore that the absence of light and the want of the alternation of day and night, the stillness of the water, and the deficiency of products of decomposition have greater influence upon plants than upon animals. In the Atlantic Ocean recent investigations have shown that animal life descends much lower; this circumstance may perhaps be due to the greater saltness of the lower zones of the Mediterranean.

Mollusca, *Serpulæ*, and Crustacea, from a depth of 1620 feet.

The facts just cited prove that some representatives of the great divisions of Invertebrate animals (Articulata, Annelides, Mollusca, and Radiata) descend to a depth of 8000 feet in the sea, and that they can live in very cold water. The microscopic Polythalamia and Polycystina, which are widely distributed in the abyssal zone, descend still lower, and occur in incalculable numbers. The calcareous and siliceous shells of these little creatures have been brought up from depths of from 10,000 to 20,000 feet. The grey mud which covers the bottom of the sea is, according to Ehrenberg, partly composed of their shells; and the species which he has studied may be distributed as follows in the various zones of depth:—

	100 to 500 ft.	500 to 1000 ft.	1000 to 5000 ft.	5000 to 10,000 ft.	10,000 to 15,000 ft.	15,000 to 20,000 ft.
Polycystina . . .	3	10	23	157	106	185
Polythalamia . .	56	73	124	136	87	9

Hence Ehrenberg concludes that these animalcules actually live at such great depths, and that the sea is filled with similar minute organisms even down to 20,000 feet. This circumstance, however, is not yet certainly proved. All the little animals brought up from these great depths were dead; and many of them (perhaps all the Polycystina) probably sank down from higher strata of water. But even if the animalcules only occupied the upper 2000 or 3000 feet of water, myriads of such microscopic creatures might live in that stratum; and their calcareous and siliceous shells, sinking into the depths of the ocean after death, would in course of time raise the sea-bottom.

The diminution of light and of the temperature of the water exert the greatest influence on the vertical distribution of plants and animals in the sea. The action of the sun's rays is limited to the upper strata of water: at a depth of 50 feet the intensity of the light is diminished and its colour becomes yellowish green; at 150 feet there is a yellowish-red twilight; and at 600 feet the distinction of day and night disappears. The temperature of the superior strata of water is governed by that of the air, and therefore differs greatly in accordance with the seasons and latitudes; this influence gradually diminishes as we descend, and disappears altogether at great depths. In the lower zones the water of the sea has a very low temperature. The upper strata are affected by the changes of day and night and of summer and winter; but lower down the temperature does not vary.

Marine currents also have much influence on the temperature of the water even at considerable depths. There are, no doubt, currents of cold water which flow from the two poles towards the equator, and, on the other hand, currents of warm water starting from the tropics and flowing towards the poles. Dr. Carpenter and Prof. Thomson found to the north of Scotland a warm and a cold region between 59° & 60° N. lat., and 4° to 12° W. long. At the surface, the temperature of the water was about 52° Fahr. (or +11° Cent.), and at 500 fathoms 46° to 48° Fahr. (or +8° to 9° Cent.) in the warm current, and 32° Fahr. (or 0° Cent.) in the cold current. The fauna in the cold current was very scanty and had a boreal character, whilst in the warm current a great abundance of animal forms were found. The warm stratum no doubt owed its temperature to the Gulf-stream, the calorific influence of which may be traced to the extreme north. Nevertheless, according to Thomson, this genial influence is lost at great depths, being felt only down to 500–700 fathoms in depth; from 2060 to 2435 fathoms deep in the Bay of Biscay that naturalist found the temperature to be 36°·5 Fahr. (or +2°·5 Cent.). In the extreme north the temperature at depths of from 8000 to 9000 feet seems to be about 32° Fahr. (0° Cent.); at least the mud brought up from such depths between Spitzbergen and the North Cape had a temperature only about 0°·5 Fahr. (+0°·3 Cent.) above this point, while that of the surface-water was 41° Fahr. (or +5° Cent.), and that of the air about 41° Fahr. (or +5° Cent.).

It is therefore clear that the animals which inhabit great depths in the sea find there, in all parts of the world, a much more uniform temperature than the animals do of the upper strata of water;

and at the same time the water is more quiet, seeing that the disturbance of storms and the undulations caused by the ebb and flow of the tides are not felt at great oceanic depths. An interesting fact, ascertained by many observations, is thus explained, that the animals of the lower marine zones have the widest horizontal distribution*; whilst those of the upper regions of the sea are as varied in their distribution as the climate and latitude in which they live. Hence the fauna and flora of the sea are modified by the action of light and heat, and by the conditions and movements of the medium which surrounds them, just like the organic beings of the dry land. But the nature of the sea-bottom also has a great influence, at least upon those plants and animals which are confined to a definite habitat; and this depends essentially upon the nature of the dry land which surrounds the sea-basin. Where great rivers flow into the sea, they carry to it a mass of material, the nature of which is dependent on that of the land through which the rivers pass. If the land is covered with an abundant vegetation, the river-water will contain a quantity of organic substances, which will give a dark colour to the mud deposited; if, on the contrary, a sandy desert forms the banks of the river, the running water will only convey sand to the ocean; if the river comes from a rocky region, it will carry with it a number of stones, which, being rolled in their course, will be deposited in the sea as rounded pebbles, the largest being first deposited. All these mineral materials which are carried to the sea in a solid form will generally accumulate in the vicinity of the mouths of rivers, and will sometimes be transported to a distance by marine currents. But rivers also contain a quantity of dissolved mineral matter, especially silica and lime, which becomes uniformly diffused in the ocean.

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* The *Idothea Baffini* of Baffin's Bay has been found also in the southern zone; the *Rhizocrinus lofotensis*, Sars, has been seen from 237 to 306 fathoms depth in the sea of the Antilles, in the Bay of Biscay, and on the coast of Norway. Hence it is manifest that marine currents exercise a great influence on the area of species, and consequently that two very different marine fauna may belong to localities very near to each other. It is probable that where the gulf-stream penetrates to great depths of the Atlantic Ocean, organic beings belonging to the same fauna will be found. The bed of the deep Atlantic seems to consist everywhere of the same calcareous mud partly formed of shells of Polythalamians, and especially of the group of Globigerini, and partly of little grains surrounded by a pasty substance, which, according to Huxley, ought to be of organic nature (*Bathybius*, Huxley).

Thus even in those regions of the ocean which are distant from any land accumulations of mineral matter are unceasingly in progress, which raise the sea-bottom. Plants and animals are also active in increasing the deposit—in the upper zones, especially, the Nullipores, Mollusca, and Corals, and in the abyssal zones the microscopic Diatomaceæ, Polythalamia, and Polycystina, which appear in myriads and effect the precipitation of silica and lime. In the open sea far from land, therefore, the deposits consist of an impalpable mud, which will form a finely grained rock; whilst at the mouths of rivers the accumulation depends on the soil through which the river flows, and the deposits consist of *sandstones*, *pudding-stones*, or *marls*.

Shell or coral limestone will be found where Mollusca have resided or polypes have built up their curious structures. In the deep and open sea there will always be a greater simplicity and uniformity in the formation of rock than in shallow water and in the neighbourhood of land. The deposits near the mouths of rivers will be thick, whilst in the open ocean, on the slopes of the submarine mountains, there will be less accumulation than in the valleys and basins below the waves.

Taking all these facts into consideration, we may understand how rocks in Switzerland, which immediately succeeded the Upper Lias, were deposited in the Jurassic sea. The Upper Lias (fig. 32) at Schambelen is followed first by a dark-coloured marl, and then by numerous beds of rock, chiefly limestones, but in part also sandstones and marls. The lower beds are generally brown, the upper ones greyish or yellowish white. The latter are called the *White Jura*, the former the *Brown Jura*; and the two form a chief constituent of the whole chain of the Jura from Geneva to Schaffhausen and Swabia. Hence the epoch in which these rocks were formed has been called the Jurassic period; but in using this term it must be borne in mind that the geographical idea of the Jura by no means coincides with the geological meaning of the word.

The Jurassic sea covered a great part of Europe, and everywhere deposits were produced; thus we find Jurassic rocks in France, Germany, England, &c. In Switzerland they form not only the northern chain of mountains known as the Jura, but also a great part of the limestone-mountains on the northern slope of the Alps, from the east end of the lake of Geneva to the Wallensee. There can be no doubt, however, that the Jurassic sea also occupied the land between these mountains and the chain of the Jura; so that throughout the whole of this wide basin we should find the Jurassic limestone (certainly at a considerable depth) beneath the sandstones and marls which now form its soil. But the Alpine Jura differs in many respects from that of Northern Switzerland; and therefore we shall treat of it separately.

In the northern chain of the Jura, between Schaffhausen and Geneva, we find innumerable spots which are filled with remains of animals; and these tell us that in that part of the country the sea-bottom cannot have been deep. This is proved not only by the abundance of animal life, but by the nature of the animals, as will be evident when we examine the following Table, in which Prof. Heer has distributed, by analogy with living species, in different zones of depth, some of the most important forms of animals found in the Jurassic rocks of Porrentruy:—

Zones of different Depths.

Shore-zone	*Patella Humbertiana, pygmæa, minuta, castellana.* *Purpura Lapierrea, gigas, ornata.* *Mytilus* 12 species. *Nerita* 3 species.
Shallow-water zone to 100 feet below low-water mark.	*Trochus* and *Turbo* 15, *Pleurotomaria* 6, *Pterocera* 13 species. *Melania* 6, *Nerinæa* 32, *Cardita* 5, *Astarte* 11 (which are also found at greater depths), *Mactra* 3 species. Sponges, Sea-urchins, Pentacrinites. Numerous Corals.
Middle zone, 100–600 feet.	*Pecten, Cardium, Modiola, Arca.* *Cidaris.* Corals.
Abyssal zone, below 600 ft.	*Arca, Pecten, Cidaris.* Polythalamia.

Numerous genera and species therefore indicate the shore and shallow-water zones, and justify the conclusion that these zones were the normal habitations of the organized substances, such as shells and corals, found in those localities. With regard to many species the zone to which they belong cannot be determined, either from their constituting extinct genera or from their belonging to genera the species of which are now met with at very different depths (such as the *Terebratulæ, Cerithia,* and *Chemnitziæ*).

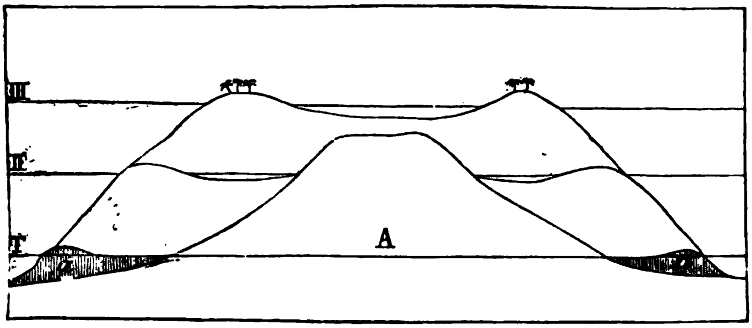
We arrive at the same result if we bring together the Jurassic animals of the Cantons of Schaffhausen, Aargau, Basle, and Soleure; they show us a considerable group of animals which cannot have lived at any great depth in the sea. The Jura of Berne and Soleure, upon which we have important works by Gressly and Thurmann, has been most thoroughly investigated, especially with respect to the ancient sea-bottom; and the little map (fig. 61, p. 120) which Prof. Heer has borrowed from Gressly's work gives an idea of the conditions which existed in this part of the Swiss Jura. In it we see the distribution of the shell-beds, which are formed of millions of well-preserved oysters, *Exogyræ, Astartæ,* &c., and of rock-beds produced by shells and corals worn and broken by rolling, swept together, and now united by a calcareous cement; whilst by the side of these a muddy bottom was spread, which has now hardened into a fine-grained rock. The coral reefs are of particular importance; and we must therefore give to them a special consideration.

The corals are undoubtedly among the most singular of animal forms. Some of them form large, round, solid bodies, and even in life resemble petrified honeycombs, fungi, and sponges; others represent branching bushes or little trees. They have been referred in former days both to the mineral and to the vegetable kingdom; but if we examine them in the living state we are soon convinced of their animal nature. We find that they possess a soft, membranous covering, in which cavities are scattered; these are surrounded by movable tentacles, which lay hold of nutritive objects and push them into the cavities (which represent the alimentary canal). Here and there this membranous tunic pushes out buds, which become developed into new animals; and these either remain attached to the tunic or separate from it, and become developed independently. In many species the tunic secretes lime from its inner surface, the deposition of which forms a firm calcareous skeleton. As the tunic grows, and gradually produces more and more small animals by budding, the calcareous skeleton, or the *polypary* as it is called, also increases, acquiring a different form in the various genera and species. Thus the polypary may be compared to a tree. In the tree, life is confined to the periphery or outer part, the bark, and the woody rings situated nearest to the bark, whilst the inner part (the mature wood) is dead; and just in the same way, in the polypary, life is solely in the bark-like tunic and the buds—only that in the polypes the individuality of the buds is more decided than in the buds and shoots of plants. In plants the peripheral vegetative part, the special agent of life, extends from the root to the summit of the stem, and by it the nutrition of all the organs is carried on; while in the polypary the tunic is by no means of such great importance; for it dies away in all the older portions, and lives and works on only in the younger branches. Hence such polyparies may continue perpetually increasing in size for thousands of years at the same stem, the younger polypes working on the outside ramifications when the older generations have long disappeared and have left only their calcareous remains. These remains, however, are of a lasting nature; and thus the corals differ essentially from plants. The wood produced by the vital tunic of a tree is of a perishable nature; the stony mass formed by the polypes resists all the changes that time can bring about.

As to the mode in which coral reefs are now formed, Prof. Heer has received from Darwin very exact ideas. The stony corals always require for their development a firm support; but this must not be at a great depth, as it has been found, by numerous investigations of the coral reefs of tropical seas, that corals live chiefly in the shallow-water and upper middle zones, and are rarely met with living below 200 feet. On the other hand they must always remain under water, and perish very quickly when exposed to the sun and air. The stony Algæ (Nullipores), which look very like corals, may, on the contrary, be dried for a time without injury, and therefore grow up to the very surface of the water, and they also extend down to the boundary of the abyssal zone. In tropical seas they generally occur associated with the corals, often forming a broad belt outside of the reefs, and thus protecting the shore; and as the nullipores construct an exceedingly dense and finely ramified mass, which grows quite to the surface of the sea, these calcareous plants form a breakwater which protects the coral-polypes within it from the violence of storms. During the ebb-tide this Nullipore-zone lies dry, frequently projecting several feet above the surface of the sea; during the flood-tide the waves pass over it, and fill its cavities and fissures with mud and fragments of all sorts, thus gradually elevating the soil. Below the coral-beds the soil is also gradually raised by the enormous quantity of animals with calcareous coverings, which establish themselves upon the reef, and whose remains repose at the bottom. Many worms, Holothuriæ, and Mollusca secrete calcareous salts, and thus produce a white mud, cementing together the fragments of coral, shells, and sea-urchins which the sea collects, and forming, as Darwin tells us, a rock. The white mud, according to Darwin, when thus solidified, presents a smooth and hard surface, as if it had been made of marble.

In many regions, such as the Sandwich Islands, the West Indies, and the Mauritius, a gradual elevation of the ground has taken place; the coral-beds, which reposed on the ancient shore,

Fig. 59.



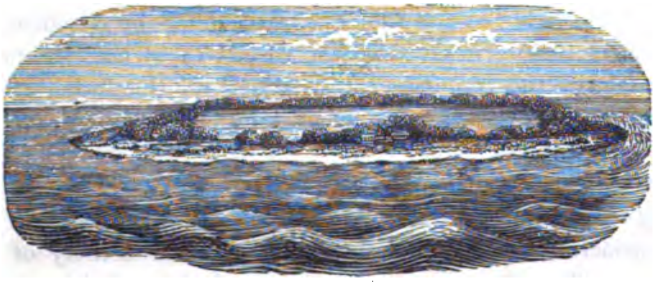
Ideal Section of a Coral Island.

Sea-level at I. producing a fringing reef (*a*), at II. a barrier reef, at III. a lagoon-island or atoll.

have risen above the level of the sea, whilst other polypes are constructing fresh shores.

In some localities a gradual depression has occurred, and has consequently modified the formation of the reefs. The process of forming coral islands in accordance with the theory of Darwin is represented in fig. 59. The horizontal line I. indicates the level of the sea about the island A; on the shores there is a *fringing reef* (*a*) surrounding the whole island. Its margin is raised because the Nullipores have established themselves around it, and the corals are thus protected against storms, and carry on their works more rapidly. The land gradually sinks, and the island therefore becomes smaller; but the polypes are building constantly in their dwellings, and the coral reef rises upwards without interruption, and the outside gains strength. In proportion as the island becomes smaller, the distance between it and the reef-wall increases, and between them is a *lagoon*. We have then (II.) an island surrounded by a ring-shaped but not entirely closed reef, called a *barrier reef*, within which there is a navigable channel or lagoon. If the sinking continues, the central island at length disappears beneath the sea, and becomes covered with corals (III.), which continue to grow uninterruptedly in the same depth of water. In this way the coral-bed takes a more or less perfectly circular form, enclosing a lake, and called a *lagoon-island* or *atoll*, such as is shown by fig. 60.

Fig. 60.



Whitsunday Atoll in the Pacific Ocean.

The lagoon is often of considerable depth, and furnished with one or more openings on the side turned from the prevailing wind. If the depression goes on, the ring of the atoll gradually breaks up into smaller islands, and finally even these disappear. All land is now submerged; the corals die at greater depths, and are covered with mud and sand. These processes have been demonstrated by Darwin from a great number of examples; and he has shown that the exceedingly numerous *atolls* and *barrier reefs* of the Pacific Ocean owe their origin to a gradual depression of the bottom, whilst the *fringing reefs* are the result of an elevation or stationary condition of the ground. In the atolls the corals form the actual soil of the island, and extend down to great depths, where, however, they are dead. They live and grow only in the upper zones, where they are constantly renewed, and are continually building on the old sea-fortresses which have lasted for thousands of years.

Corals occur in all seas; but the reef-building species are not now found in the cold and temperate zones, and even in tropical seas they are by no means to be met with everywhere. They do not occur about the Galapagos Islands, or the west coast of Central America, or in the Atlantic Ocean, except in the Bermudas [and at Key West, in Florida]. The Indian and Pacific Oceans are dotted over with atolls and barrier reefs, the latter sometimes bordering the shores of large masses of land; thus, off the north-east coast of Australia, for a distance of 1000 miles, there is a broad reef separated from the land by a channel from 10 to 25 fathoms in depth, and in breadth from twenty to thirty miles. In the southern hemisphere coral reefs extend to the twenty-ninth degree of latitude; in the northern hemisphere they reach to 30° in the Red Sea, and, under the favouring influence of the warm Gulf-stream, to 32° 15′ at the Bermudas. Throughout this immense area, therefore, the formation of calcareous rock is still being effected by myriads upon myriads of little architects.

In ancient times this process of forming calcareous rock was going on even in Switzerland; and the Swiss are indebted for a considerable portion of their rocks to the activity of the polypes. The Jurassic sea presents the Swiss with islands and reefs, which agree perfectly with those of existing tropical seas. Individual corals, and here and there even reefs, occur in the older Jurassic rocks; but they do not appear in great abundance until the time of the White Jura. In this region they formed limestone beds, often attaining a considerable thickness, which have received the name of "Coralline limestone." These strata consist of a mass of stony corals, frequently more or less crystallized. The inner structure has been often destroyed by crystallization; but the external form and the striation and sculpture of the coral and its cells are very well preserved. They are usually beautifully white; but the stems and branches are sometimes flesh-coloured. Between these corals, which are often still upright, and sometimes attain a diameter of 2 to 3 feet, many remains of other animals (Sea-urchins, Sponges, Mollusca, and Crustacea) are imbedded and united by a calcareous cement into a more or less compact rock. It is in the interior of the coral reef, in the former lagoon of the atoll, that the animals have been best preserved. The shells of the Mollusca are uninjured, and often still retain their pearly lustre; the sea-urchins show us their elegant tubercles and striæ and their finely sculptured spines; they were often imbedded in the mud which filled up the interior of the lagoon, just as in the lagoons of the present day, in which, according to Darwin, a fine calcareous mud accumulates at the bottom.

In the Swiss Jura it is not uncommon to meet with thousands of individuals of the same species buried either near to each other, or in layers of different ages. The bivalves are found with their two shells in the position occupied during life. Hence, at some remote epoch, these animals must either have been overwhelmed by an avalanche of mud and sand, or must have gradually perished by the lowering of the sea-bottom, drawing them down and placing them in a new condition unsuitable to their prolonged life. The rock has preserved the colony as it once existed.

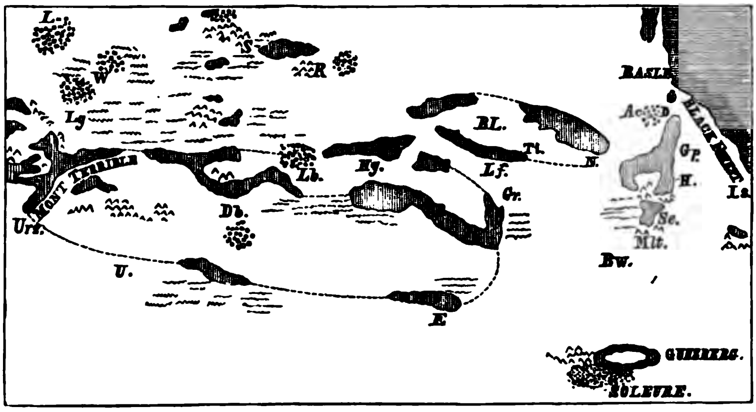
On the outer margin of the coral reefs we often observe layers of rock composed of comminuted remains of animals mixed confusedly together, which show us the action of the surf. This is the case on the western side of Gunzberg and on the margins of the reefs of Hochwald and Rädersdorf.

Besides species which occur everywhere in the Jurassic sea, nearly every reef and bed of rock possesses its peculiar forms. This is particularly striking with respect to Sea-urchins, Corals, and *Comatulæ*, which in many places are associated together as if in families. It is worthy of notice that, according to Gressly, the compact limestone of the Jura, slightly siliceous and filled with remains of bivalve Mollusca, sometimes precedes the banks of corals. The first occupants of the ground seem to have been principally *Pholadomyæ, Mytili, Modiolæ*, &c., which prefer sandy depths where they may bury themselves. Oysters, sponges, and sea-urchins soon follow in the same locality.

At Porrentruy, and in many other places, calcareous strata destitute of corals, and formed of sandy and muddy masses, are found above the coral-beds; and higher up the corals appear again, and are then again covered by deposits without corals, thus manifesting a succession of changes in the conditions of life of the marine fauna.

The following little Map (fig. 61) indicates the distribution of the coral reefs in a part of the Swiss Jurassic sea. It shows

Fig. 61.



Coral Reefs of the Jurassic Sea.

The parts marked with vertical lines represent the reefs, the portion with horizontal lines the Black Forest, the small circles the shell-banks, and the small triangles the beds of marine animals which have been rolled and broken by the tides and tempests; the undulated lines indicate muddy ground; letters indicate names of places, as follows:—Urs. St. Ursanne; Lg. Largue; L. Liebsdorf; W. Winkel; U. Underdevelier; Db. Delsberg; S. Sondersdorf; R. Rädersdorf; Lb. Liesberg; Hg. Höggerwald; E. Envelier; B. Bärschwyl; Lf. Laufen; Gr. Grindel; Ti. Tillingen; BL. Blauenberg; N. Nentzlingen; Ae. Aesch; D. Dorneck; Gp. Gempen; H. Hochwald; Se. Seeven; Mlt. Meltingen; Bw. Beinweil; Ls. Liesthal.

us the reefs of the Cantons of Basle, Soleure, and Berne. In Jurassic times, as in the Liassic period, the Black Forest and the Vosges were dry land, into which penetrated a wide bay, which occupied what is now the low land of Alsace. This bay furnishes us with a great quantity of corals and sea-shore animals, which prove that the west side of the Black Forest had a coast with a *fringing reef,* and that, at the southern extremity, from Dorneck past Gempen and Seeven to Meltingen, it obtained the form of a *barrier reef* surrounded by deposits of mud and breccia. Further to the west, atolls make their appearance. The lagoon-island north of Laufen, and which surrounds the Blauenberg, Prof. Heer regards as an atoll. There are three reefs in this locality which enclose a lagoon. In the same neighbourhood a second, larger atoll is found, to the north of which is a reef interrupted only in a few places, and which may be traced from Mont Terrible by Delsberg to beyond Bärschwyl for an extent of about twenty-four miles, and is bounded on the south by the reefs of Envelier, Moutier, Grandval, and lower Develier. Its lagoon has the form of a long narrow ellipse. The coral banks of the Höggerwald rest in some degree on this atoll, which may be called the Delsberg atoll, and probably formed a second, small lagoon with the same sort of elliptical contour as the larger one, and connected with it by a channel (in the neighbourhood of Liesberg). At the Mont Terrible (near St. Ursanne) the coral reefs were largely developed, and may be traced into the vicinity of Porrentruy, where they attain considerable dimensions at Pont Abel. At Gunzberg there is a very small atoll, connected with which is the turtle-bed of Soleure, occupying the upper part of the celebrated quarries of that Canton. Large numbers of turtles probably visited this locality for the purpose of depositing their eggs.

North of the great Delsberg atoll the Jurassic rocks are manifested by several colonies of Mollusca which inhabited muddy shallow waters at Largue, Winkel, and Liebsdorf. The shells of these animals are still in their natural position, one on the side of another, and were evidently overwhelmed and buried alive by a torrent of mud. Above, there are a few scattered coral reefs, the largest of which commences about two miles from Sondersdorf, and extends to Rädersdorf (in the vicinity of Firt); this reef is particularly interesting on account of the beautiful specimens of coral found there. Passing on towards the west we still meet with similar reefs in various places, as between the Échelle and the Lake of the Brenêts, in the valley of Joux, some little islands on Mont Risoux, in the valley of the Orbe, and in the vicinity of the Perte du Rhône (at Dorche near Chanay). But the number of reefs diminishes considerably towards the west; the southern portion of the bay of Alsace was the richest district for coral reefs in the Jurassic sea. It is remarkable that coral reefs are entirely absent in the Jura of Aargau and of Schaffhausen—that is to say, on the southern and eastern coasts of the Black Forest. Reefs are also not to be found in the south-west of Swabia, whilst they reappear on the north-east of the Alb, and are distributed upon the heights between Bopfingen and Ulm, as well as westward at Blaubeuren and in the environs of Urach. The great coralline rock of Arneck, near Ulm, is composed, according to Quenstedt, of countless millions of corals; it furnishes the stone for the pavement of Ulm and also the principal material for the fortifications of that city, which was thus prepared by these little creatures millions of years ago. Large coral reefs are also known in other parts of Germany, and in France and England; so that in Jurassic times reefs rose into being and spread about in Europe as they now do in the Indian and Pacific Oceans; and it is an interesting problem to ascertain the distribution and form of these reefs in the European Jurassic sea.

Reverting to the coral reefs of Switzerland, the question may arise whether they were covered by the sea or rose from it like the islands which are so numerous in the Pacific. Coral islands which rose above the sea occur in the Cantons of Basle and Soleure. In Basle the coralline limestone of the Pfäffinger Schloss and of the Castle of Neuenstein is covered with a carbonaceous deposit, which, although of very little importance, indicates firm land; and near Dänikon, in the neighbourhood of Olten, a fine pinnate leaf of a Cycad (*Zamites Feneonis*, Br.) has been discovered. In the Western Jura, also, there were coral islands covered with vegetation, as is shown clearly by the fine Cycadean leaves which have been discovered

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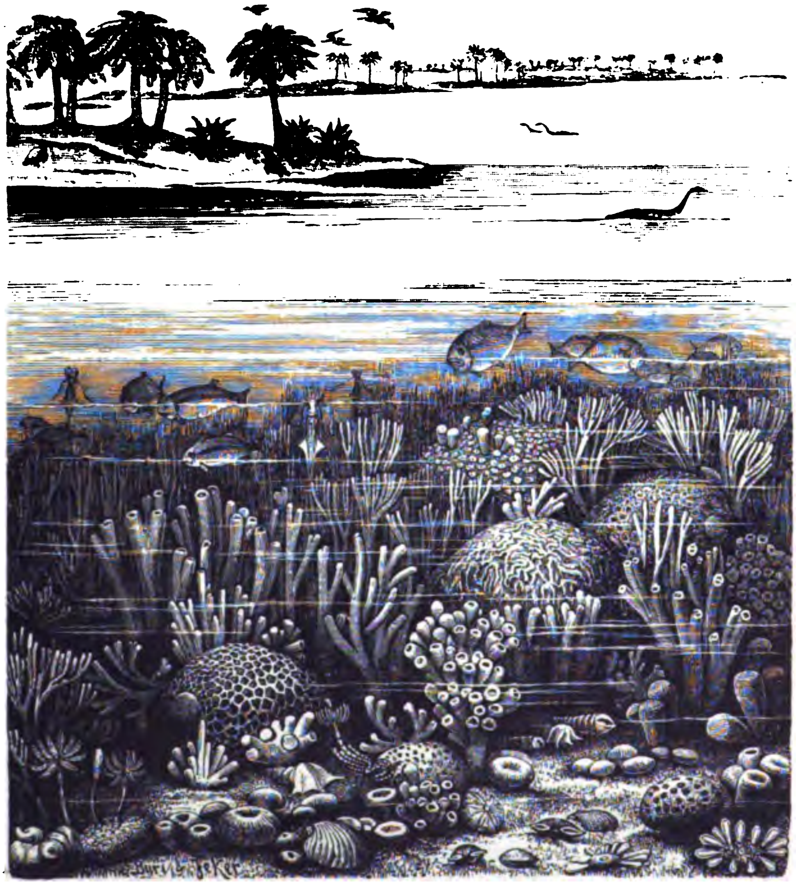

on Mont Risoux and near Dorche. There must also have been an island clothed with Cycads in the neighbourhood of Lyons, as fine large leaves of such trees have not unfrequently been found there.

The accompanying plate is an attempt to give a notion of the appearance of the ancient Swiss lagoon-islands or atolls. It shows us the Cycads (*Zamites Feneonis*) which crowned these islands, the Turtles which crawled out of the sea to deposit their eggs upon the shore, the winged Saurians (Pterodactyles) flying towards the land, and the long-necked Plesiosaurs seeking their food in the vicinity of the shore; whilst in the depths of the sea we see the coral forest rising up towards the surface of the water, and the multifarious animal life which accompanied the growth of coralline* rocks.

In the north and west of Switzerland the Jurassic sea was chiefly shallow, and in the Gulf of Alsace it was fringed with coral reefs along the coast-line; southwards it was sprinkled with reefs which united to form atolls. Towards the west the number of reefs diminishes; but even there some of them rose into islands from the blue waves of the sea, and were crowned with feathery Cycads.

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* The corals represented are as follows:—*Isastræa helianthoides* with angular cells and large head-like polyparies; further to the right, *Mæandrina rastellina* with winding ridges, and close to it *Stylina castellum* with round cells; in the corner to the right, *Microsolena expansa*, of which the polypary is narrowed towards the base. The *Thecosmiliæ*, *Cladophylliæ*, and *Isocoræ* form the greater part of the shrub-like corals; from the thick polypary of the *Isastræa*, the *Thecosmilia irregularis* spreads towards the left, while behind it is the thick-branched *T. trichotoma*, and to the right *T. crassa*; in front of it two or three specimens of the short-branched *Confusastræa dianthus* are seated; in the left corner we see *Isocora Thurmanni*, and more in the background the dense bushes of the *Cladophylliæ*. The reversed conical corals in the right-hand corner represent the *Montlivaltiæ*. Among these corals we see, in the left corner, seated on a coral, three *Apiocrini*, and near these a group of sponges (*Cnemidium* and *Scyphia*), associated with which is a sea-urchin (*Pygurus Blumenbachi*, Ag.). Upon the coral against which the latter leans a *Serpula* has taken up its abode and is seen spreading out its delicate tentacles. Scattered in the foreground are various Mollusca, such as *Diceras arietinum* (in the left corner), *Pterocera oceani*, *Nerinæa bruntrutana*, and *Pecten avaricus*, Et. In the right-hand corner there is a thick-spined sea-urchin (*Cidaris Blumenbachi*). The bottom is covered by a turfy growth of Nullipores; from the forest of corals, Belemnites shoot up towards the surface of the water, where two species of fish (on the left *Lepidotus lævis* and on the right *Pycnodus*) play about.

Of the nature of the Jurassic sea in the region which is now covered by the Miocene or Molasse, extending over nearly the whole of the plain country of Switzerland, we know nothing, as the old Jurassic soil is there concealed from us. It comes to light again along the Alps, and constitutes a part of the highest Swiss mountains. That these Alpine Jurassic beds were formed at the same epoch as those of the north-west of Switzerland, is proved undoubtedly by the fossils which they contain; and it is therefore very remarkable that the beds should differ in important characters. In the first place the thickness of the deposits in the Alpine Jurassic beds is much greater than those in the north-west; hence the depth of the sea must have been greater, since a very deep sea-basin is necessary for the production of a bed of rock several thousand feet thick. This view is confirmed by the great uniformity of the rock masses and the great scarcity of fossils, in which respects the Alpine Jura differs so greatly from that of the north-west. There are, however, places in the Jurassic Alpine limestone which contain an abundance of fossils; but such fossils only prove the existence of rare and scattered colonies, and there are whole mountain masses and widespread beds of rock in which no fossil remains have yet been found. These strata were probably formed in the desert abysses of the sea. True coral reefs have not as yet been discovered in the Alpine Jurassic deposits; but a few isolated corals occur, such as *Isastræa helianthoides* (Pl. IX. fig. 7), on the Tödi. Of the Mollusca, the Ammonites predominate; and these are regarded as animals specially fitted for open-sea life by their shells and air-chambers, like the allied *Nautili*, which are also represented in the Alpine Jurassic beds. We may indicate, as positions in the Alpine Jura particularly rich in populous colonies, the Gonzen, the Guppenalp, the Firenbänder on the Glärnisch, the summit of the Schilt, and several places in the chain of the Stockhorn. The older Brown Jura is generally much richer in coral reefs than the White Jura, and consists here and there of innumerable fragments of small marine animals.

A further remarkable and complete difference between the Alpine Jurassic limestone and that of the north is the colour of the rock. The Alpine Jura is always of a much darker colour, and forms a compact blue-black limestone. This difference of colour is the more striking because these two nearly parallel Jurassic chains run south-west and north-east at a distance of 45 miles apart, and throughout their whole length of about 150 miles the colour of each chain remains the same. The dark colour of the Alpine Jura is due to the presence of carbon, probably derived from seaweeds. The best explanation of this phenomenon may be furnished by the Sargasso-sea. The Sargasso-weed (*Sargassum bacciferum*) covers the Atlantic Ocean for a space of about 40,000 square miles between 22° and 36° N. lat. and 25° and 45° W. long. (Greenwich), forming, in certain parts, such dense masses that ships driven into this Sargasso-sea have sometimes much difficulty in working their way out. As these Sargasso-fields have existed for centuries, or even thousands of years, they will doubtless exert a great influence upon the formation of the mud which is gradually collecting in those localities upon the sea-bottom. The sea is there very deep, and the mineral deposits in a sea so distant from land must be very scanty; the conditions are very unfavourable to the preservation of the plants; and their remains which reach the bottom will therefore form only a black mass, giving a dark colour to the deposits produced. The calcareous matter deposited under these circumstances will acquire a dark colour, and there will be prepared, in the depths of the sea, a material which, if raised and exposed to the air and sun, would produce a rock similar to the Swiss Alpine Limestone. Darwin describes the colouring of limestone formed from corals, near Keeling Island, in those places where there were great masses of seaweed. The same process may have gone on in Switzerland during the Jurassic period. If we imagine along the Alps a deep marine valley below the surface of a sea covered with seaweeds like the Sargasso-sea, we have all the conditions necessary to explain this remarkable Swiss phenomenon of the Brown Jura, which has already repeatedly occupied the attention of the alpine geologists.

In examining the flora and fauna of the Jurassic sea, we shall confine ourselves to some of the most important forms. Bronn (in 1858) catalogued from the Jura (including the Lias), in all, 3831 species of animals—namely, 119 Zoophytes, 542 Radiata, 2362 Mollusca, 324 Annulosa, 373 Fishes, 108 Reptiles, and 3 Mammalia. Since then, a considerable number of new species have been made known. We have at present no complete catalogue of the species found in Switzerland; but Thurmann and Etallon have made a catalogue of the species from the vicinity of Porrentruy. It contains 797 species—namely, 42 Polypes, 216 Radiata, 482 Mollusca, 37 Annulosa, 12 Fishes, and 8 Reptiles. As so many species have been met with in so small a space, which, moreover, embraces only the uppermost section of the Jura (the White Jura), we may assume that at least twice the number have been collected from the Jurassic beds of the whole of Switzerland, and that the Swiss collections probably contain more than 2000 species of the animals of the Jurassic sea.

We have already seen (pp. 108, 109) that the microscopic Polythalamia are widely distributed in the great depths of the sea, and that their little shells assist greatly in the formation of the sea-bottom of the Atlantic. Lately the remains of these little creatures have been found in the Jura. The researches of the Rev. H. Zwingli and Dr. Kubler* have led to the discovery of many species in the Lias, and of a still larger number of species in the Brown and White Jura. These gentlemen have described and figured 34 species from the Lias, 56 from the Brown Jura, and 78 from the White Jura. Some of the principal forms of these Jurassic species are shown (highly magnified) in the accompanying figure (fig. 61 B).

These species belong to five different groups of the Polythalamia (or Foraminifera). The *Lagenæ* and the *Cornuspiræ* have only one cell, which, in the latter, is arranged in a spiral; they form the order Monostegia. In the *Nodosariæ*, *Frondiculariæ*, and *Dentalinæ* there are several cells arranged on the same straight line; they form the order of the Bacillar Polythalamia or Stichostegia; whilst the group of the Helicostegia, in which the shell, composed of several chambers, is rolled into the form of a snail-shell, is represented by the *Cristellariæ* and *Flabellinæ.* The *Textilariæ* have chambers arranged in two or three series, and do not form a spiral; they belong, with the genera *Globulina* and *Vulvulina,* to the group of the Enallostegia; while the remarkable genus *Ophthalmidium* must be classed among the

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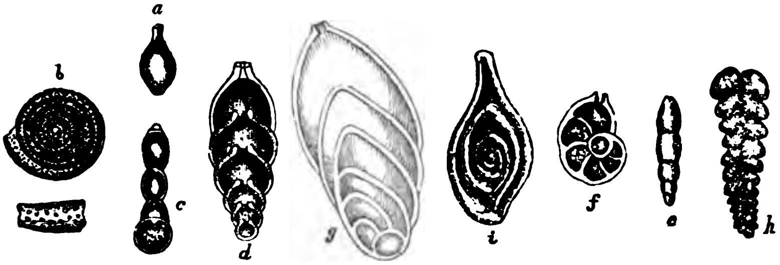
* Microscopical Illustrations of the Primæval World of Switzerland (Winterthur); New Year's Journal for 1866; and the Jurassic Foraminifera of the Swiss Jura, described and figured by the Rev. H. Zwingli and Dr. J. Kubler (Winterthur, 1870).

Fig. 61 B.



a. Lagena helvetica, from the strata of Birmenstorf; (according to Prof. Rupert Jones, Geol. Mag. vol. x. no. 5, this *Lagena* is the *Lagena lævis;*) *b,* the *Cornuspira helvetica* (a *Spirulina* according to Prof. R. Jones), from the *Opalinus*-clay of Schambelen; *c, Nodosaria cuspidata,* from the Brown Jura of Betznau; *d, Frondicularia globulosa,* Betznau; *e, Dentalina eichbergensis*; *f, Cristellaria communis,* Birmenstorf; *g, Flabellina jurassica,* Betznau, common in the Brown Jura; *h, Textilaria flexa,* Baden; *i, Ophthalmidium carinatum,* Betznau, which is considered by Prof. Rupert Jones a Spiroloculine *Miliola.*

Agathistegia, in which several chambers are placed around a single axis. The Stichostegia and Helicostegia include the greater part of the Jurassic species; the Monostegia and Enallostegia are only met with here and there, but in great numbers, so that they may be regarded as having taken an active part in the formation of the Jurassic deposits.

The polypes which constructed the coral reefs are larger than these Polythalamia, which are visible only under a high magnifying-power. The Jurassic sea was very rich in species of coral-polyps, as is shown by the White Jura of Porrentruy, from which 107 species have been described. We can only mention a few of them.

A glance at the Plate representing the coral reefs of the Swiss Jurassic sea (p. 123) shows us some of the most striking and abundant species on a very diminutive scale. Among these species we may distinguish, by their appearance, three principal forms:—

I. The large dome-like corals;
II. Shrub-like forms; and
III. Cup-shaped corals.

The dome-shaped occur in a great variety of forms, some of which are shown in the Plate. We have some corals with six- or seven-sided calices, which become conical below—the *Isastrææ*. *Isastræa helianthoïdes* from the Tödi is represented of the natural size in Pl. IX. fig. 7. The bottom of the calice is occupied by a central spot (the *columella*), on which numerous indistinctly notched ribs converge from the margin. The edges which separate the calices are sharp, but in places thicker and broader. This species occurs also in the Jura, where eight other species have been discovered.

In other large dome-like corals we find rounded, closely approximated calices, with raised margins, from which externally numerous striæ start and traverse the surface of the coral. These are the *Stylinæ*, of which *Stylina castellum*, Edw. & H., a fragment of which is represented (Pl. IX. fig. 8), may serve as an example. It forms irregular round masses, as large as a man's head, or larger. The calices are nearly ⅐ inch in diameter; they have in the centre a little disk usually bearing a small projecting tubercle in its middle, round which the numerous septa are placed. Of this genus, which still exists, 17 species have been discovered at Porrentruy. At the same place the *Microsolenæ*, with their stellate striæ, are still more abundant; the *Microsolena expansa* of itself forms whole rock masses.

The *Mæandrinæ* display peculiarly tortuous ridges. Of these, *M. rastellina* (*Dendrogyra rastellina*, Et.) has spread to a large extent at Porrentruy; and a variety of it (*M. subrastellina*, Et.) sometimes forms corals 1½ foot in diameter.

Of the shrub-like corals the most abundant are the *Thecosmiliæ*. They constitute large stocks which are much ramified, producing a perfect forest of twigs and branches, and forming clumps from 10–18 feet in length and breadth. In the Plate (p. 123) we see the short *Thecosmilia irregularis* with spreading branches, the taller and more ramified *T. crassa*, D'Orb., and

T. trichotoma, whose stems and thick branches issue in threes united together.

A similar species is *Confusastræa dianthus,* Et., which forms short thick-branched bushes, one of which in the Plate stands in front of the *Isastræa,* and behind the *Pterocera*s. The *Cladophylliæ, Rhabdophylliæ,* and *Isocoræ* have a mutual resemblance one with another. They form shrubs with numerous thin cylindrical branches, which in the *Isocoræ* have the appearance of tufts.

The *Montlivaltiæ* are remarkable forms. They are reversed cones, terminating above in a large circular calice or cup, traversed by numerous rays (septa). A group of the *Montlivaltia grandis* is shown in the right-hand corner of the Plate.

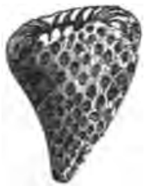
In the coral reefs of the sea, as well as in land-forests, many animals find a secure dwelling-place and abundant food. In the fissures and clefts, and among the branches of the corals, innumerable sponges, starfishes, sea-urchins, and mollusca take up their abode. Many of these seek only a safe habitation; but others, as the *Holothuriæ* and some fishes, feed on the polypes. In the Indian Ocean shoals of shining blue fishes (a species of *Sparus*) may be seen through the transparent water, browsing, like herds of cattle at pasture, on the coral reefs.

The Jurassic coral reefs of Switzerland contained a number of living animals, which, in like manner, no doubt, formerly dwelt and obtained food among the polypes. Sponges and sea-urchins are particularly abundant, and they deserve especial notice in the fauna of the Swiss Jurassic sea.

All the world is acquainted with the common sponge; but it is less generally known that a great number of sponges occur in the shallow water and middle zones of the sea, covering the bottom with a coat of the most beautiful colours, which vary from a dark blue to a reddish or sulphurous yellow. Whether the sponges of the Swiss Jurassic sea were also adorned with these colours we do not know, although we may suppose so; but that they possessed the same variety of forms is proved by the numerous species which are preserved in all stages of the Jura. We see among them forms resembling fungi, figs, cylinders, plates, and cups, and having a wrinkled, cellular, fissured, or reticulated veining of the outer surface. Two of these are represented in figs. 62 & 63.

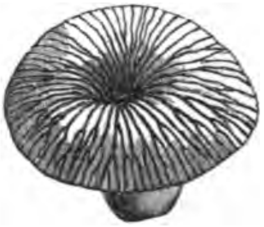
Cnemidium Goldfussi (fig. 63), from Randen, which has long been known, is found sometimes 6 inches in length and breadth. The middle of the round cavity is drawn into a funnel; and the margin is turned over to the extent of about an inch.

Fig. 62.



Scyphia obliqua.

Fig. 63.



Cnemidium Goldfussi (much reduced).

Scyphia obliqua (fig. 62) was known to Wagner, Scheuchzer, and Lang, and compared by them to a petrified fig. These cup-sponges, many species of which, often of large size, are still living, are hollow internally, and represent a cup composed of a tissue of reticulated fibres. In the species here delineated the outside is furnished with numerous irregular pores. About a dozen other species have been collected in the Canton of Aargau (especially near Birmenstorf); and with them are associated numerous species of *Tragos*, *Spongites*, &c.

The sea-urchins of the Swiss Jurassic sea are still more numerous in species. Thurmann has discovered seventy-five species in the White Jura of Porrentruy alone; and to these must be added numerous forms from the older stages. Whilst we know from Schambelen only two or three species with fine spines, many forms distinguished by remarkably large and peculiarly formed spines (*radioles*) make their appearance in the Jurassic limestones.

The most abundant are the species of *Cidaris*, a genus which is still living and has been met with at great depths in the sea. These sea-urchins have large, cylindrical, spindle-shaped, or club-shaped spines, beset with small spines or tubercles. *Cidaris coronata* (Pl. IX. figs. 3, 4, half nat. size), the commonest sea-urchin of the Lägern and the Jura, may be recognized by its depressed form and its very large, but not numerous, tubercles (fig. 3), to which elongate-ovate spines were attached. In the coralline rocks the large-spined *Cidaris Blumenbachi*, Ag. & Des. (*C. florigemma*, Phil.), is widely diffused; it is shown in the right-hand corner of the Plate (p. 123). *Hemicidaris crenularis*, Ag. (Pl. IX. fig. 6, half nat. size), is still more remarkable from its extraordinarily large, club-shaped spines, which, however, are very rarely still attached to the test. Detached spines are not unfrequently found in the White Jura of the Cantons of Aargau, Soleure, and Neuchâtel. *Rhabdocidaris nobilis*, Münst. (Pl. IX. fig. 1, half nat. size), from Randen, has still larger spines beset with spinules; they sometimes attain the length of a foot. In other Jurassic Echinids the spines are wanting, and the tests are only furnished with tubercles, as *Clypeus* (Pl. IX. fig. 2, *C. sinuatus*, half nat. size) and *Pygurus*, fine specimens of which occur in Switzerland, and are confined to the Jurassic and Cretaceous formations. This applies also to the genus *Holectypus* (Pl. IX. fig. 5, *H. depressus*, Lesk. sp., formerly *Discoidea*), of which the form here figured occurs so abundantly in one bed of the Brown Jura, in the Canton of Basle, that it has received the name of the Discoidean marl.

The Pentacrinites, which have been referred to in the Lias (p. 70), are also distributed in the Middle and Upper Jura. To them must be added the *Apiocrini*, in which the cylindrical stem is dilated into a pear-shaped body, which bears ten arms. *Apiocrinus polycyphus*, Ag., and *A. Roissyanus*, D'Orb. (shown in the left-hand corner of the Plate), occur in the Swiss coralline limestone, as at Mont Terrible, and *A. Meriani*, Des., is still more widely diffused in the upper beds of the White Jura.

The number of polypes, sea-urchins, and sponges of the Swiss Jurassic sea is very great, but is far exceeded by the number of the mollusca, which present a wonderful diversity of forms. Among the most remarkable types a few species are here noticed, which have either had a large share in the formation of the rocks, in consequence of their individual abundance, or which are especially characteristic of particular divisions of the Jurassic rocks.

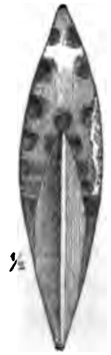
Of the genus *Nautilus*, with which we met as early as the

Muschelkalk (p. 45), thirteen species occur in the Jurassic rocks. The Giant Nautilus (*N. giganteus*, D'Orb.) here attains a diameter of 30 centimetres, or nearly a foot, and is one of the largest known shells; it is exceeded only by the *Nautilus bisulcatus* of the Swiss Lias, the diameter of which is sometimes as much as 1 metre (3·371 feet).

The Ammonites reach their fullest development in the Jura. They occur in great abundance, and sometimes of so large a size that they have not unjustly been compared to cart-wheels; and they also possess an admirable variety of forms. From the Jura and Lias of Switzerland 162 species have already been described, some of the most important of which are represented in figs. 64–72.

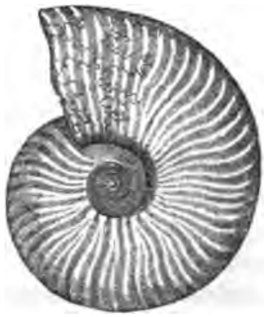
Some of them (such as *Ammonites discus*, Ziet., fig. 64) had perfectly smooth shells (which probably, during the life of the animal, possessed a beautiful pearly lustre) and a very sharp keel, whilst in others the shells are traversed by delicate striæ, or even by strongly projecting transverse ribs, which, in their course, exhibit a varied line. In *A. Murchisonæ* (fig. 65) the striæ are bent forwards like a sickle; and this is the character of a whole group of Ammonites (the *Falciferi*). In *A. biplex*, Sow. (fig. 66), which occurs in extraordinary abundance in the Swiss White Jura, the sharply projecting ribs are forked into two branches towards the back, while in the nearly allied *A. poly-*

Fig. 64.



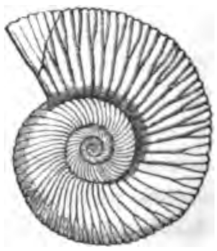
Ammonites discus, Ziet.

Fig. 65.



Ammonites Murchisonæ, Sow.

Fig. 66.



Ammonites biplex, Sow.

plocus, Dek., they are divided into a still greater number of branches. In *A. Parkinsoni*, Sow. (fig. 69, from the Oberblegi Alp), figured by Lang from the Lägern, the ribs project very decidedly, and only a portion of them are forked at the circumference. On the back they do not reach the middle, which is occupied by a furrow; and the dorsal furrow becomes characteristic of this species (fig. 69 *b*). In the similar *Ammonites Martinsii* (fig. 67, also from the Oberblegi Alp) the ribs are wide; and between those which cross the whole whorl shorter ribs are inserted towards the keel. *A. Morrisi*, Opp. (fig. 68), forms, with *A. macrocephalus* and some allied species, a peculiar group characterized by a very rapid inflation into a globular form, the last whorl being large and the keel rounded. *A.*

Fig. 69 *a*.

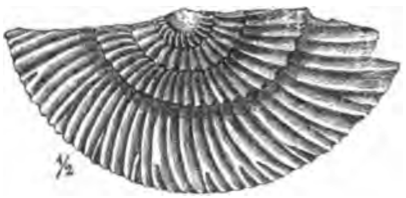


Fig. 69 *b*.

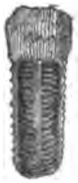


Fig. 69 *a*. *Ammonites Parkinsoni*, Sow., Oberblegi Alp.
Fig. 69 *b*. Dorsal view, reduced.

Fig. 67.

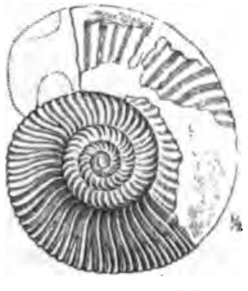


Fig. 68 *a*.

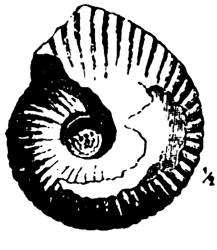


Fig. 68 *b*.

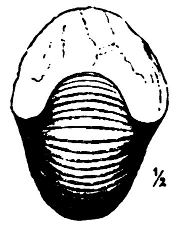


Fig. 67. *Ammonites Martinsii*, D'Orb., Oberblegi Alp: half nat. size.
Fig. 68. *Ammonites Morrisi*, Opp., Oberblegi Alp: *a*, side view; *b*, back: half nat. size.

Morrisi has rather close simple ribs, running right across the back.

In many Ammonites the shell is adorned with tubercles, teeth, and spines, as in *A. ornatus*, Schl. (fig. 71, a very small specimen), in which the sides are furnished with elegant ribs and a row of tubercles, and the back is bordered by two rows of spines. The *A. Ruppellensis*, D'Orb. (fig. 72), is remarkable for its very large spines; and in the exceedingly elegant *A. Jason*, Rein. (fig. 70), the sides of the aperture are produced into two tongue-shaped ears. This is a species which is widely distributed in Europe, even to the Ural; but in Switzerland it has been observed only in a few places (at Hornussen in the Canton of Aargau, at Grand Caudon in the Canton de Vaud, and in the Stockhorn chain). *A. Ruppellensis* is also rare: it is found at Obergösgen, near Olten, and at Birmenstorf, while the beautiful *A. ornatus* occurs throughout the whole Jura.

Fig. 70.

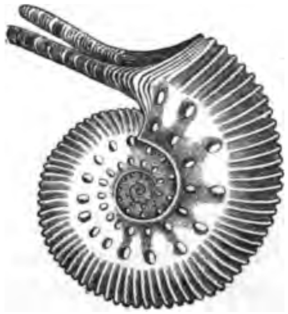


Fig. 71.

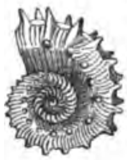


Fig. 72.

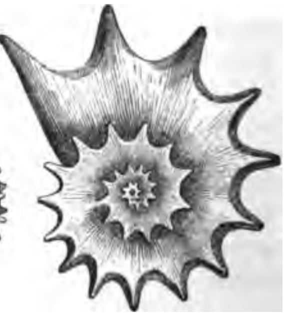


Fig. 70. *Ammonites Jason*, Rein. sp. Fig. 71. *Ammonites ornatus*, Schl.
Fig. 72. *Ammonites Ruppellensis*, D'Orb.

Like the Ammonites, the Belemnites, which are allied to them, attain their greatest development in the Jurassic sea. The Museum at Zurich contains sixty-six species from the Lias and Jura of Switzerland, the majority coming from the Upper Lias and from the Brown Jura and the Lower White Jura. Being predacious animals, they must have committed great ravages among the inhabitants of the sea, especially as many of them reached a very considerable size. The spindle-shaped shells of the *Belemnites giganteus* and *B. baculoides* of the Swiss Brown Jura form rods of from 1 to 2 feet in length; and the whole animal was probably twice as long. Many species are extraordinarily abundant; thus the *Belemnites semihastatus* occurs by millions in the *Ammonites-ornatus* clay of the Canton of Aargau.

These Cephalopods are the largest Mollusca of the Swiss Jurassic sea, and also the most numerous in species; but many other genera are associated with them. Of the genus *Melania*, which still exists in the seas and rivers of the tropics, species 6 inches long (*M. striata* and *M. gigas*) occur in the White Jura of Porrentruy. Like them are the *Chemnitziæ* (*C. Clio*, D'Orb., fig. 77, one third nat. size) with long spindle-shaped shells terminating in a fine point, and the *Nerineæ*, of which the shells are sometimes smooth, sometimes deeply striated, or even beset with elegantly arranged warts and tubercles (*N. nodosa*, Volz.). Of this genus we know twenty-one species from the Jura of Porrentruy alone, some of them being above 6 inches in length

Fig. 73. Fig. 74. Fig. 75. Fig. 76. Fig. 77.

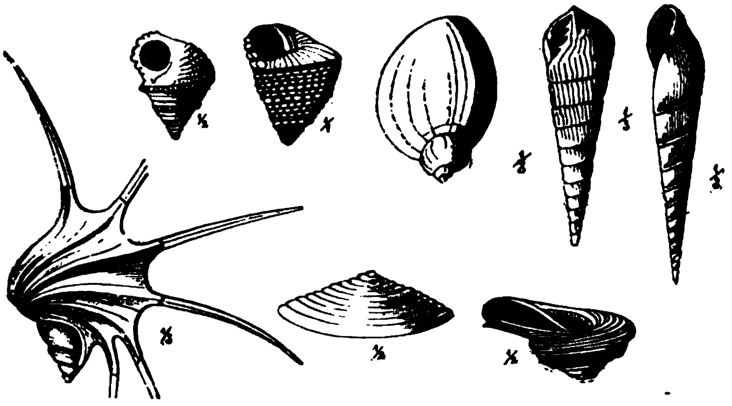


Fig. 78. Fig. 79. Fig. 80.

Fig. 73. *Turbo tegulatus*, Münst.
Fig. 74. *Trochus angulatoplicatus*, Münst.
Fig. 75. *Natica gigas*, Stromb. sp.
Fig. 76. *Nerinea bruntrutana*, Thurm.
Fig. 77. *Chemnitzia Clio*, D'Orb.
Fig. 78. *Pterocera Oceani*, Br.
Fig. 79. *Patella castellana*, Thurm.
Fig. 80. *Ditremaria* (*Pleurotomaria*) *discoidea*, Röm. sp.

(such as *N. arrarica,* Et.). *N. bruntrutana,* Thurm. (fig. 76, one third nat. size), is so abundant in the coralline limestone there that the rock is called *Nerinea*-limestone. The genus *Natica* (fig. 75), recognizable by its wide last whorl, is represented by large and abundant species, such as *N. grandis, N. gigas,* and *N. semiglobosa,* Et. The species of *Trochus* (fig. 74) and *Turbo* (fig. 73) resemble living forms, such as are still to be found in abundance on the seashore. Nearly allied to these are the *Ditremariæ,* of which several large species (*D. discoidea,* fig. 80, half nat. size) occur at Porrentruy. The *Murices* and Limpets (such as fig. 79, *Patella castellana,* Th., from Porrentruy) indicate the neighbourhood of the shore; and the remarkable wingshells (*Pterocera*), with their digitate outer lip, must certainly have lived in shallow water. One species (the large *Pt. oceani,* Br., fig. 78, from Porrentruy) may be traced from the old coralline limestone to the comparatively recent Portland limestone; at Porrentruy it occurs by thousands in some beds, whilst it is wanting in the intervening strata, showing that the conditions favourable to the existence of the wingshells have occurred there at various times and again disappeared.

The Bivalve Mollusca in the Swiss Jurassic sea were nearly twice as numerous as the Univalves; but they nevertheless do not show so great a diversity of forms. As rock-forming species, Switzerland has:—the Oysters—*Ostrea acuminata* (fig. 81), *O. Marshii, O. bruntrutana, O. cotyledon,* &c.; the nearly allied *Exogyræ,* distinguished by having the beak rolled inwards—*E. virgula* (fig. 82); and the small, nearly circular equal-valved Astartes—*A. supracorallina,* D'Orb. (fig. 83), which occur occasionally in millions. Some of the Lampshells (as *Terebratula impressa,* fig. 88, and *Rhynchonella lacunosa,* fig. 87) also fill whole beds of rock, which have received from them the names of *Impressa*-beds and *Lacunosa*-beds, as also the great *Pholadomyæ* (*P. paucicosta,* Röm., fig. 84), of which nineteen species have been collected in Porrentruy alone. Of Scallops and *Limæ* the same locality has furnished sixty-six species, generally with large and strong shells, often adorned with furrows and tubercles. Besides these, the Swiss have numerous species of *Mytilus, Arca, Cardium, Cyprina,* and *Pinna.* Particularly remarkable forms are *Diceras arietinum,* Lam. (fig. 85), distinguished by its large,

Fig. 81.

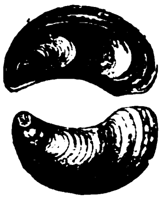


Fig. 82.

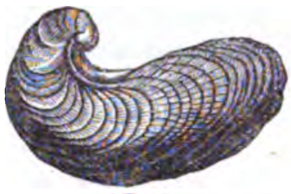
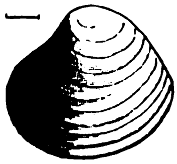


Fig. 83.



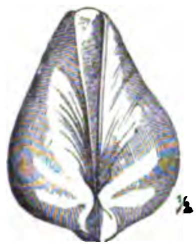


Fig. 84.

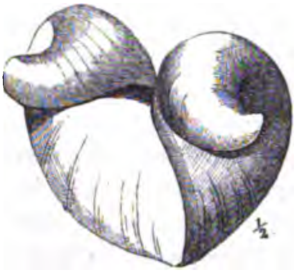


Fig. 85.

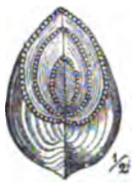


Fig. 86.

Fig. 81. *Ostrea acuminata*, Sow., from Frick.
Fig. 82. *Exogyra virgula*, Dfr. sp.
Fig. 83. *Astarte supracorallina*, D'Orb., enlarged, from Porrentruy.
Fig. 84. *Pholadomya paucicosta*, Rœm., half nat. size, Porrentruy.
Fig. 85. *Diceras arietinum*, Lam., half nat. size, Porrentruy.
Fig. 86. *Lyriodon suprajurensis*, Ag., half nat. size, Porrentruy.

Fig. 87.

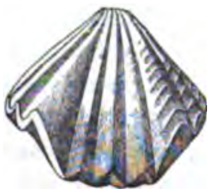


Fig. 88.

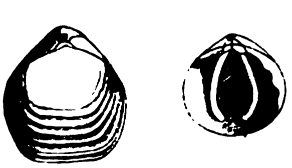


Fig. 89.

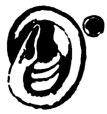


Fig. 87. *Rhynchonella lacunosa*, Schl. sp., var. *arolica*, Opp., from Birmenstorf.
Fig. 88. *Terebratula impressa*, Br.: *b*, interior of the shell.
Fig. 89. *Serpula gordialis*, Schl., from Porrentruy.

spirally twisted beaks, and *Lyriodon suprajurensis*, Ag. (fig. 86), characterized by its triangular shell adorned with striæ and tubercles. Of the genus *Lyriodon*, there are two species still living in the Indian seas, whilst the *Diceras* became extinct during the Tertiary epoch.

Of the great class of Annelida, which was doubtless numerously represented in the Jurassic sea, only those species have been preserved which constructed calcareous tubes (the *Serpulæ*). In these tubes the animals live, protruding from the mouth of the tube their long and elegant tentacles, which, in the living species, display a variety of colours. These *Serpulæ* have been found most abundantly in Switzerland in the White Jura of Porrentruy (twenty-one species), where some of them (such as *S. subflaccida*, Et., *St. laufonensis*, Et., *S. gordialis*, Schl., fig. 89, and *S. Thurmanni*) occur in great quantities.

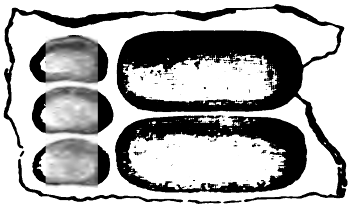
It is very singular that the Crustacea must have been rare in the Swiss Jurassic sea; at least they have hitherto been found only in a few places and merely in imperfect fragments. From the Jura of Porrentruy ten species have been distinguished, but only from isolated claws and ill-preserved fragments of the test; among the genera, the Brachyurous Crustacea, called Crabs, make their first appearance in the genus *Prosopon*. In the summer of 1862, Escher de la Linth discovered on the Fulen, at the highest summit of the Mürtschenstock, remains of Crustacea, but, unfortunately, not sufficiently well-preserved to determine the species. That in other localities of the Jurassic sea there was a great abundance of Crustacea, is proved by about 50 species being found in the deposits of Solenhofen and Nusplingen. At these places the same genera (*Glyphea, Eryon*, and *Penæus*) reappear which had been already discovered in the Lias of Schambelen, although the species in the Jura are different and the forms more varied. Of the Prawns found some were a foot long; and several of the species of *Eryon* had a very singular appearance, with their broad carapace much notched at the margin and in the front.

The Swiss Jura has not hitherto furnished many Vertebrata. Here and there a few teeth and some remains of bones of Crocodiles (*Ischyrodon Meriani*, Myr., *Machimosaurus*, and *Madriosaurus Hugii*, Myr., *Dracosaurus Bronnii, Megalosaurus Bucklandi*, and *Sericodon Jugleri*, Myr.), of an Ichthyosaur and a Plesiosaur have been found, showing that as late as the period of the White Jura (in which they have been discovered at Porrentruy) these marine monsters had visited the Swiss Jurassic sea; but as yet no deposit has been met with to prove that they regularly inhabited the Jurassic region.

We have already noticed (p. 121) the occurrence of turtles in the quarries of Soleure, where 9 well-marked species and 4 or 5 doubtful ones have been collected in the Upper White Jura (Strombian). According to Prof. Rütimeyer, they belong to the family of the marsh-tortoise (*Emys*), but yet approach the true marine turtles in some of their characters. Some of them are of considerable size; and their carapaces and breast-plates and occasionally their heads have been preserved. Rütimeyer has distributed them under three genera (*Thalassemys*, *Platemys*, and *Platychelys*). At Soleure, fine specimens of *Platychelys Oberndorferi*, Wagn., have been found; similar fossils occur in the lithographic stone of Kelheim. This species is remarkable for its large, much-embossed dorsal plates, thus resembling the freshwater Tortoises. But the great abundance of the species found seems to indicate that these Chelonians sought their food in the sea and not on the dry land; for the little coral-islands could scarcely have furnished sufficient nourishment to such a vast number of individuals. In the Canton of Neuchâtel, and in places on the French frontier, true species of *Emys* have been found; near the Brenets the *Emys Jaccardi*, Pict., and near Moirans the *E. Etalloni*, Pict., have been met with. The *Emys Jaccardi* has a nearly circular shell about 14 inches in length, shown in fig. 91 on a very reduced scale. The White Jura of Porrentruy contains remains of species of *Emys* as well as of Sea-turtles (*Cheloniæ*).

Only a small collection remains of the fishes which lived in the Swiss Jurassic sea. About a dozen species have been found; but of most of them little besides the teeth is preserved. For instance, in the genus *Pycnodus*, the teeth have a round or oval form, they are smooth and shining-black in colour (fig. 90), and hence have received from the quarrymen the name of "stone eyes." They stand in several rows in the interior of the mouth, and are very variable in form and size. Of this genus about 8 species have been discovered in the Swiss Jura; and with them are associated several sharks (*Syphenodus longidens*, and *Hobodus Bressaucourtianus*, Et.) and a large *Lepidotus* (*L. lævis*, Ag.). Of the *Lepidotus*, which was a fish about 3 feet long, of the general form of a carp, and with large rhomboidal scales, a fine specimen has been found in Soleure, and a few remains at Porrentruy.

Fig. 90.



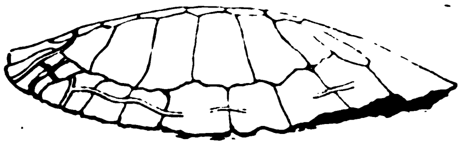


Fig. 91.

Fig. 90. *Pycnodus gigas*, Ag.: teeth.
Fig. 91. *Emys Jaccardi*, Pict., one sixth nat. size.

Considering the abundance of animal life which peopled the Swiss Jurassic sea, at least in certain places, there can be no doubt that vegetation in numerous forms covered the rocks and the rocky shallows. Circumstances, however, have been very unfavourable for the preservation of soft and delicate marine plants; so that most of them have either disappeared without leaving any trace, or they have been so much injured that it is very difficult to determine them. A few characteristic forms, however, have been collected by Prof. Heer. The most important species has been described by Quenstedt as a *Fucus hechingensis*; but, in Prof. Heer's opinion, it belongs to the Nullipores, which have assisted so materially in the construction of the coral islands. The Swiss *Nulliporites hechingensis* differs from *Fucus* by its rigid, cylindrical stems, and by its branches spreading in all directions* and, as in the Nullipores, being much divided and having extremities frequently thick and obtuse;

* The species of *Chondrites* are found spread out over flat slabs of rock, whilst the *Nulliporitæ* furrow the stone in all directions, which proves that the latter had rigid branches incrusted with lime, and that the *Chondritæ* crept along the ground. The branches of the Nulliporites often fall out, when round holes and cylindrical tubes are left in the stone.

Nulliporites also pushed on in thick masses, and formed large beds, so that it filled entire rocks, furrowing the stone in all directions. This fossil is distributed throughout the whole White Jura. Prof. Heer has seen it from Oberbuchsiten, in Soleure, in the limestone of the tunnel at Baden (Pl. IX. fig. 18), in the Effingen bed at Lauffohr, in the Birmenstorf bed of Büron east of Gansingen, near Birmenstorf, and from the summit of the Schilt in the Canton of Glarus (Pl. IX. fig. 19). A second, nearly allied species (*N. argoviensis*, Mösch, Pl. IX. fig. 20, from Birmenstorf), distinguished by its longer and less approximated branches, occurs near Birmenstorf, Villingen, and Zünikon; a third (*N. angustus*, Heer, Pl. IX. fig. 21), with very thin tortuous branches, is found in the upper Effingen beds, and is common in Bargen on the Randen. In Swabia, according to Quenstedt, *Nulliporites hechingensis* is distributed throughout the whole country of Zollern from Hundrück to the heights of Thalheim, and forms a considerable bank of rock on the side of the railway at Geislingen.

Another remarkable Jurassic form of seaweed is the genus *Zoophycos* (*Taonurus*, Fisch.-Oost.). These were large marine plants, in which several leaves stood in whorls or in a very depressed spiral around a central axis. The leaves are strongly curved, and traversed by numerous longitudinal nerves which run together at the base and apex. These plants appear in enormous masses, filling whole rocks in the *Humphriesianus*-beds of the Middle Jura, as well as in the upper Schambelen-beds*. At Ehrendingen in the Canton of Schaffhausen, there are some deposits of the same plants which were long ago noticed by Escher de la Linth and Stutz. Prof. Renevier has recently discovered some *Zoophyci* in the lower Brown Jura of the Canton de Vaud (near Arveyes, district of Ollon, in the rocks of the Fares); and Dr. Ch. Gaudin has found them near Roche. In the same beds of the Brown Jura, in France, they have been observed; and they are met with from Macon to the south of Provence, as well as at Auriol in the Gard, and at the Aveyron. This remarkable form of plants was distributed, at the time of the Lower Jura, on the surface of the sea from Randen to the south of France, probably forming the chief mass of the seaweeds of that period. It probably occupied the place now taken by the *Laminariæ* of the present day in northern seas. Prof. Heer has four species, the most abundant being the *Zoophycos scoparius* (*Chondrites scoparius*, Thioll.) (fig. 92), which closely resembles the *Zoophycos brianteus*, Villa, sp. Near Arveyes it fills the rock with its dense masses, deposited one over the other. The leaves are on an average about 4 inches long, and traversed by numerous curved longitudinal nerves, which are forked here and there. In a second species (*Z. ferrum equinum*, Heer) the leaves are narrow and bent almost into the form of a horseshoe. In the specimen from Arveyes, represented in fig. 93, of half the natural size, four such leaves are placed in a whorl. The third species (*Z. procerus*, Heer), also from Arveyes, is characterized by its remarkably large leaves (more than 1 foot long), and by

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* Here, according to Mösch, the *Opalinus*-clays form a deposit 190 feet thick, above which are the *Murchinsonia*-beds with a thickness of 28 feet; upon these is a deposit with *Monotis Münsteri*, *Ammonites Humphriesianus*, *A. Romani*, *A. Sowerbyi*, *Ostrea pectiniformis*, and *Belemnites giganteus*, and over this a limestone-bed, about 22 feet thick, full of *Zoophycos*. These are covered by a bed 4 feet thick, with *Cidaris Schmidlini*; and over it the *Ornatus*-clay and the beds of Birmenstorf have been deposited.

Fig. 92.

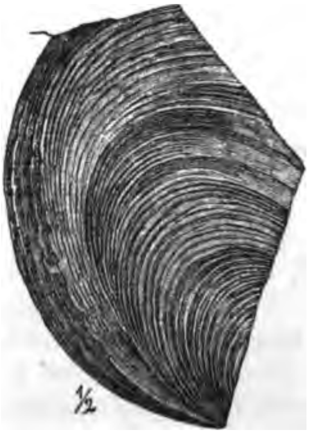

Fig. 93.

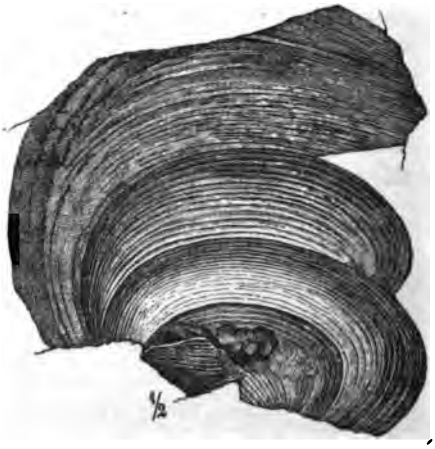

Fig. 92. *Zoophycos scoparius*, Th. sp.

Fig. 93. *Zoophycos ferrum equinum*, Heer, from Arveyes, in the Canton de Vaud.

the numerous transverse striæ which occupy the intervals between the simple, strong main nerves.

Chondrites æmulus, Heer (Pl. IX. fig. 17, from the Oxfordian limestone of Menveraud), is a very delicately formed plant, which Prof. Heer has received from the Cantons of Vaud and Soleure (the middle White Jura of Oberbuchsiten). It resembles the Liassic *Chondrites* (p. 69); but it is of a more slender form, has no opposite branches, and its terminal ramifications stand at a wider angle. Still more delicate is a species from the upper Brown Jura of Grenairon (*Chondrites setaceus*, Heer); whilst a second species from the same locality (*C. inæqualis*, Heer) has long branches more stretched out, and the thicker branches are as broad as the stems. This species also occurs at the pass between Rothenbrunn and Hüttlerthal in the Vorarlberg.

The species of *Cylindrites* have very thick, nearly cylindrical stems and branches; they are abundant in the White Jura, and by themselves compose whole beds. The *Cylindrites lumbricalis*, Kurr. sp., is found also in the Lower Lias; *Cylindrites Langii*, Heer (Pl. IX. fig. 22), the stems of which, 1½ to 2 lines in thickness, branch at very acute angles; it covers whole slabs of rock in the White Jura of the Canton of Soleure (the Virgulian of Sommiswyl), and is also not uncommon in the quarries of Rhyfluh and of Lauffohr (Effingen beds). *Cylindrites Cartieri*, Heer, has a still larger stem; it covers entire beds near Oberbuchsiten; and its branches, four lines in width, grow almost at right angles with the stem.

Some very enigmatical structures are represented in Pl. IX. figs. 9–14. In order to give them a name, Professor Heer has called them *Gyrochorte*. They reach a length of about 6 inches, and are 1½ line broad, forming little bands with parallel sides and notched margins. In the commonest species (*Gyrochorte vermicularis*, Heer, Pl. IX. figs. 9, 10, enlarged) a furrow runs along the middle, bounded by two rows of small, obtusely rounded warts, which are a little inclined forwards, imbricated, and slightly twisted spirally at the side (Pl. IX. fig. 10, *b*). In a second species (*Gyrochorte comosa*, Heer, fig. 12) the central furrow is indistinct, and the warts or scales are more strongly bent forward, while in a third (*G. ramosa*, Heer, fig. 11) the bands are branched. Quenstedt regards these bands as tracks of starfishes; but such light creatures, with their five rays, could not possibly have produced the deep tracks which have been so strongly marked, and which are rather to be attributed to chaplets of eggs of marine mollusca. These impressions occur very abundantly from Swabia, in all the Swiss Jura, in the Brown Jura, in the upper bed of the *Ammonites opalinus*—as well as at Schambelen, at Betznau, at the Frickberg near Frick, and in the Canton of Basle near Delsberg. Whole slabs are often covered by these long bands crossing each other in various directions. It is very singular that these impressions again make their appearance in the Miocene or Molasse of the Gurten, and of the Saane near Fribourg, as shown by the specimens represented in Pl. IX. figs. 13, 14. But the reappearance of these traces becomes less surprising if we suppose the impressions to be owing to the spawn of mollusca; for many Jurassic genera are still found in the Tertiary sea, and the eggs do not afford the means of determining the species.

In the Swiss Jurassic sea were several islands—for instance in the Canton of Basle, in the neighbourhood of Olten, and of the Mont Risoux in the Val de Joux, and further on, near Dorche (in the vicinity of Chanay, in the French department of the Aisne). From these localities Prof. Heer has obtained four species of plants—a conifer (*Araucarites Meriani*, Heer), two cycads (*Zamites Feneonis*, Heer, and *Z. formosus*, Heer, fig. 94), and a fern (*Cycadopteris Brauniana*, Zigno, fig. 96). The conifer (Pl. IX. fig. 16, from the beds of Effingen and of Rubendorf, in the Canton of Basle) had its twigs densely covered with leaves, like the Chilian *Araucaria;* the rather long rigid leaves are obtusely rounded at the apex, and furnished with delicate longitudinal veins indicated by rows of points (Pl. IX. fig. 15, fragment of a leaf, enlarged). *Zamites* possessed pinnate leaves, with the pinnæ traversed by several longitudinal veins of equal strength, as in the *Pterophylla*, which appeared so abundantly in the Keuper flora; but the pinnæ of the Jurassic *Zamites* are inserted upon the upper surface of the leaf-stalk, which they almost entirely cover with their bases. In the leaf from Mont

Risoux*, represented in fig. 94 (*Zamites formosus*, Heer), the leaf-stalk is concealed in the stone, whilst the position of the pinnæ shows that they nearly overlie each other at the base. The pinnæ are broadest in the middle, and narrowed towards both the base and the apex; at the base they are obtusely rounded. In *Z. Feneonis*, Brongn., the pinnæ are more parallel,

Fig. 94. Fig. 96.

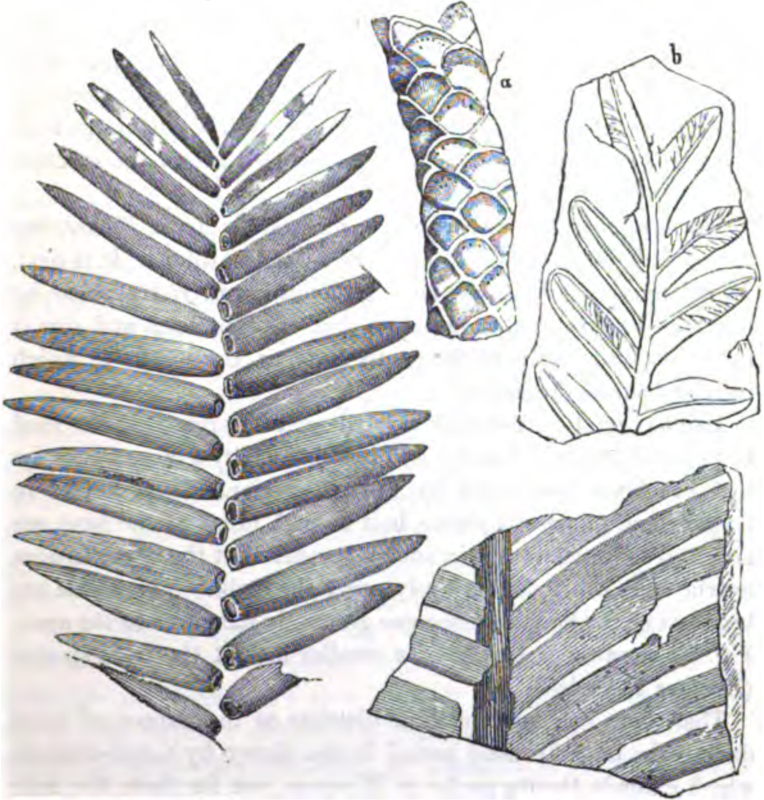

Fig. 95.

Fig. 94. *Zamites formosus*, Heer, from Mont Risoux.
Fig. 95. *Zamites Renevieri*, Heer, from Vuargnez.
Fig. 96. *Cycadopteris Brauniana*, Zign., from Dorche near Chanay.

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* A fragment of a leaf, which also seems to belong to this species, was found by M. Mösch in the Geissberg bed of Aarburg, near the bridge over the Aar.

and are not narrowed in the same way towards the base. The leaves are much longer, and are more than 4 inches broad. Prof. Heer has seen fine leaves of this species from Dänikon, Dorche, Lyons, and Ulm. The plant was therefore spread over all these coral-islands. The *Cycadopteris* forms a genus of ferns specially belonging to the Jura; its fronds are pinnate and leathery, and the lobes are traversed by a broad median vein, and edged with a flat border. When the latter occurs, the median portion of the lobe was probably covered with fruits, the uncovered margin forming this distinct strip. The fragment of a stem, fig. 96, comes from the same locality, and probably belongs to the same plant. It is closely covered with large leaf-scars, the dots on which indicate the places where the vascular bundles passed into the stalks.

Dr. Greppin has discovered a remarkable fruit (*Euterpites Ivernoisi*, Thurm. sp.) in the Oxfordian of Châtillon. It is oval, 18 millimetres (about $\frac{7}{10}$ inch) in length, and is traversed by eighteen longitudinal ridges; so that both in form and size it approaches the fruits of the genus *Euterpe*, the species of which inhabit tropical America.

Land-vegetation formerly existed near Vuargnez, in the road to Sepey (Canton of Vaud); and in this locality a large Cycadean leaf has been discovered by Prof. Renevier. It is 2 feet in length; and numerous pinnæ, half an inch broad at the base, are attached to its leaf-stalk in such a manner that the opposite ones overlie each other, and entirely cover the stalk. The pinnæ are broadest at the base, and become gradually narrower to the apex. Fig. 95 shows a fragment of a smaller leaf of the same species (*Zamites Renevieri*).

That there was land in these districts of the Canton of Vaud during the later Jurassic period is also shown by a coal-deposit, which extends thence as far as Wimmis, not far from the lake of Thun, and can be traced at the northern extremity of the Gastlose, near Jaun, on both sides of Klus, and on the slopes of the Holzersfluh, near Weissenburg, Erlenbach, and Wimmis. Coal can only be produced by land-plants; and firm land is requisite for their growth. Marine animals, however, are also found at these places; so that there must have been a sea-shore. The animals agree with those of the Upper White

Jura (the Portlandian); and the above-mentioned plants are also very characteristic of the Upper White Jura. The same fern has been found in the White Jura of Swabia (at Nusplingen) and in Northern Italy (at Rozzo); it belongs to a genus which forms a peculiar type of Jurassic rocks. To these land-plants we may add an *Equisetum* (*E. veronense,* Zign.?), some short fragments of the stem of which, not sufficient for perfectly certain determination, have been discovered in the *Opalinus*-clays of Betznau and Mols. Of the three Cycads one species (the *Zamites Feneonis*) has been noticed elsewhere in the White Jura; but all belong to the genus *Zamites,* which occupied an important position in the Jurassic flora.

If we look into neighbouring countries in which land-plants have been preserved, we find some near Nusplingen in Wirtemberg, in the north of Bavaria in the celebrated deposit of the lithographic limestone of Solenhofen, in Yorkshire and the isle of Portland in England, and at Rozzo in the Veronese. Both in England and in Italy the character of the flora is due to numerous Cycads whose form is analogous to that of the *Zamiæ* of South Africa. With them some Conifers appear—a species of pine, an *Araucaria* (*A. veronensis,* Mass.), and a tree (*Arthrotaxites*) which resembles the Australian genus *Arthrotaxis.* Numerous branches of the *Arthrotaxites,* densely covered with scale-like leaves, occur abundantly in Solenhofen and Nusplingen, proving that in the Jurassic period this tree grew to a large extent in the forests of those localities.

If we compare the flora of the Jurassic period with that of the Lias, we shall find between them several links of affinity, although the species are very distinct. Deciduous leafy trees do not yet appear; arborescent club-mosses and most of the woody Equisetaceæ (horsetails), so abundant in the Coal period and in the time of the Keuper, have disappeared: the woody vegetation is formed by gymnospermous trees [such as conifers and cycads] of species similar to those now living in the southern hemisphere.

Like the coral islands of the Pacific, the islands of the Swiss Jurassic sea appear to have had but a small number of species of plants. Of the fauna of the Swiss Jurassic islands we know, at present, only a few reptiles. A considerable number of species, however, are seen in the lithographic limestone of Solenhofen and in the Jurassic deposits of England and France. From these we learn that large grasshoppers leaped about the ground, gigantic dragonflies swept through the air, and industrious white ants * built up their earthy dwellings; there were also capricorn beetles, Buprestidæ, water-scorpions, long-legged spiders, and Myriopoda. Lepidoptera make their first appearance at Solenhofen, where a nocturnal species (*Bombyx antiqua*, Redtb.) is found. At Solenhofen the dragonflies are the most abundant insects, and to maintain them there must have been at that time fresh water on the land, as the larvæ of dragonflies live exclusively in water. This habit also characterizes water-bugs. The lithographic stones were probably formed near a vast tract of land in a quiet bay, where the sediment would be deposited by the united action of lakes and brooks. This land comprised an abundant fauna of insects; and the locality was favourable to the development of Pterodactyles, a dozen species of this flying reptile having been already found at Solenhofen.

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* Prof. Heer has seen two species from Solenhofen—one, very large and beautiful, in the Museum at Haarlem, and another in the Museum of Munich; the latter has been described as a moth (*Tineites lithophilus*, Germ.). A species allied to the tropical forms, but larger than any now living, has recently been described by Dr. Hagen (*Termes heros*, Hag.). This naturalist has carefully investigated the Neuroptera of Solenhofen, and determined thirty-seven species, of which twenty-seven are dragonflies. Some of them belong to extinct genera, but others to such as now live in America and Australia (such as *Petalia*, *Petalura*, and *Phenes*). The wings of some of the species measure 6–8 inches across. Of the Ephemeridæ and *Perlaria* there are some very remarkable species, and there are some genera (*Chrysopa* and *Nymphes*) which are now met with only in the southern hemisphere. A few cockroaches and gigantic Locustidæ represent the Orthoptera; and the Rhynchota or Hemiptera are represented by tall water-bugs (*Belostoma*), by *Nepa*, and by a land-bug nearly 2 inches long.

In England insects have been discovered at Stonesfield near Oxford, and in the Purbeck formation, which stands on the boundary-line between the Jurassic and the Cretaceous series. These deposits contain cockroaches, grasshoppers, white ants, dragonflies, and numerous beetles, of which the Buprestidæ are the most numerous family; besides these there are land- and water-bugs, and several Cicadellinæ, some Tipularian flies, three ants, and three Lepidoptera. Many of these species are closely allied to the insects of Solenhofen.

Here also dwelt the most ancient bird of the primæval world, the *Archæopteryx macrura*, Owen*.

Mammals had already made their appearance at this period. The first traces of Mammalia are found in the Trias of Richmond in Virginia, United States, and at the upper limit of the Keuper (the bone-bed) in Wirtemberg and England, where small teeth of mammals have been discovered. From the Jura [or Oolite] of England we already know eighteen species (four from Stonesfield, and fourteen from the Middle Purbeck). The remains are all of small animals belonging to the marsupial class.

The Jurassic islands were characterized by a very peculiar and remarkable fauna. Prof. Heer does not know any part of the earth where similar forms of life are met with. The islands of the Pacific Ocean present the nearest resemblance to the Jurassic world. Like the Pacific islands there were formerly in Europe numerous islands and groups of islands affording a safe retreat to marine animals. The shores were adorned with magnificent Cycads, great Araucarias, and Arthrotaxites, under the shade of which some crocodiles with powerful breastplates watched for their prey. On the beach were many turtles, which came there to deposit their eggs in the sand. At that time, as now, the submarine rocks were covered with wonderful coral forests, in which there worked millions upon millions of small animals; and in the thick darkness of this stony thicket, countless multitudes of richly coloured mollusks concealed themselves. Sponges, sea-urchins, and starfishes formed here and there, as at the present day in the warmer and tropical zones, wonderful submarine gardens, which they enameled like flowers, in varied yellow, blue, and red colours. And does nothing remain of all this exuberance of life, of all this rich development of vegetation, incalculable periods of ages ago? Is all lost and annihilated of the millions of wonderful organisms which then enjoyed life and formed an harmonious whole? Certainly not! The marvellous history of these organized beings has not been lost to man. Their fossil remains buried in the earth have preserved the record which is read in the interior of rocks and in impressions left upon them.

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* This bird was of the size of a fowl, and differed from all existing birds by its long tail, consisting of twenty vertebræ, each of which supported a pair of quill-feathers agreeing in all respects with those of living birds. From the remarkable form of the tail, the animal was at first regarded as an intermediate link between birds and reptiles, until Owen showed that it had nothing in common with amphibious animals. In the embryonic state the tails of all birds have several vertebræ, which, however, are not afterwards developed; but in the case of this primæval bird, the development in the tail of the embryo is continued to mature growth.

Jurassic rocks, which form, in the north-west of Switzerland, a mountain-chain rich in picturesque beauty, also belong to the series of the limestone-mountains of the Swiss Alps; they were witnesses of the life of that primæval age, and by it were brought into being; so that to the Jurassic epoch Switzerland is indebted for much of its land, and for a large portion of its mountains and its rocks.

The thickness of the Swiss Jurassic deposits may be estimated at not less than 2500 feet. The strata of the White Jura of Porrentruy, according to Thurmann, measure 817 Swiss feet. In the Canton of Soleure the same thickness, according to Lang, is given to the White Jura; but to this must be added about 900 feet for the Lower White Jura and for the Brown Jura; so that the total thickness of Jurassic rocks in Soleure amounts to about 1700 feet (or with the Lias to about 2000 feet). The Jura of Neuchâtel is stated by Desor and Gressly to be 2490 feet thick. In the Canton of Aargau, according to Mösch, the White Jura is about 630 feet thick, and the Brown Jura is 790 feet in thickness. The Jurassic formations of the Swiss Alps, however, are of still greater thickness.

It is manifest that the formation of such important sediments must have occupied an immense length of time, which is shown not only by the thickness of the deposits, but also by their nature and by the plants and animals contained in them. If we examine the Swiss Jurassic islands, we soon see that they are composed of a great number of beds. In one place we find hard calcareous rocks, which furnish an admirable building-material; and in another locality are soft, sandy marl-beds, strata which easily sink away. Rocks of pure carbonate of lime are met with, and strata containing a great amount of clay; limestones composed of a perfectly uniform and very finely grained material are found, as well as other rocks which consist entirely of thick grains and have a lenticular structure. It is evident that these different kinds of rocks must have been deposited under different circumstances, and that there must have been frequent modifications of the nature and abundance of the material from which the rocks originated. Even the colour of the stone is very variable. In general the lower beds following immediately upon the Lias have a dark, and frequently a brown colour, whilst the upper beds are blackish blue in the alpine regions, and the colour of the northern Jura is white or yellowish white.

Hence the Jura has been divided into two great sections—the *Brown* and the *White Jura.* As these colours extend also to the fields and vineyards, the soil of which has been produced by the weathering of these two kinds of rock, the districts of the Brown and White Jura may generally be distinguished at a distance. Most geologists refer the Lias to the Jurassic period, and thus divide the Jura into three great sections, of which the Lias, on account of the dark colour of its marls, is called the *Black Jura.* The colour of the Liassic marls is due to the great quantity of organic substances which they contain; and the Brown Jura owes its colour to the amount of iron in its rocks; so that at the time of their deposition a good deal of iron must have been in the sea.

The organic contents of Jurassic beds testify to the slowness of their formation. In the region of Porrentruy, which belongs entirely to the Upper White Jura, more than twenty-seven beds, lying one over the other, may be distinguished, each of them presenting certain peculiarities in its fossils. Thus the *Nerineæ* (fig. 76) and *Pterocerata* (fig. 78) occur in perfectly definite beds, separated from each other by beds in which these fossils do not exist, but which contain a quantity of bivalve shells. Hence during the upper Jurassic period the conditions of life for different forms of animals frequently changed in this locality, and one fauna succeeded another as animals found themselves able to live or died away. Thurmann admits about twenty successive faunas for the White Jura of Porrentruy. The same process is going on in our present seas, and also on the land, but it can only produce striking results in very long periods of time.

An arrangement of the principal divisions of the Jura into stages is given in the following tabular view, showing the types of animals comprised in the different Jurassic strata:—

GENERAL TABLE OF THE SWISS JURA.

III. WHITE JURA.

UPPER WHITE JURASSIC STAGE.

Alpine Zone.

PORTLAND AND KIMMERIDGE.

Limestone Mountains from Tour de Mayen, above Yvorne, to Weissenburg; Vuargnez, in the Canton of Vaud. Road of the Ormonts, from Aigle to Sepey; coals of Simmenthal; shales of Balfries; summit of the Mürtschenstock.

Northern Zone, from Geneva to Schaffhausen.

PORTLAND.

Purbeck. Freshwater formation of Villers le Lac.

Virgulian, with *Exogyra virgula,* from Porrentruy; Langnau, heights of the Hasenmatt, in the Canton of Soleure, Egerkingen.

Strombian, with *Pteroceras oceani, Nerinea bruntrutana, Elsgaudiæ,* &c., from Porrentruy, the quarries of Soleure, the neighbourhood of Grenchen, Querkluse above Oberdorf. Also the *Vettinger beds* of Mösch, at Endingerberg, Rieden, the quarry near Schönenwerth, Wangen, and the upper beds of the Lägern (coralline limestone of Nattheim).

KIMMERIDGE.

Astartian, with the *Astarte supracorallina, Exogyra bruntrutana,* &c., at Porrentruy, Hasenmatt. Also the *Baden beds,* eastern wall of the Baden tunnel—Endingen—at Randen (white gamma); and the *Letzi beds,* lithographic stones of the Bötzberg, Olten, Wangen.

MIDDLE WHITE JURASSIC STAGE.

CORALS.

Alpine Zone.

Wallenstadt, Alpine Jura.

Northern Zone.

Coralline Limestone. Val Travers and St. Sulpice, in the Canton of Neuchâtel; Caquerelle; Mont Terrible; Pont d'Able, &c.; Laufen, St. Claude. White limestones of Egerkingen, Soleure, Würenlingen, Ryfluh, &c.

Chailles beds. Only in the western Jura as far as Basle.
Crenularis-beds of Mösch in Aargau: at Ryfluh; Lauffohr; Bötzberg.
Geissberg beds. Geissberg; Bötzberg; banks of the Aar at Brugg and Stille; Aarau; Gösgen; Olten; south side of the Lägern; Baden tunnel.

OXFORD.

Alpine Zone.

Limestones of Schilt and of Guppenalp at the Glärnisch.

Northern Zone.

Effingen beds (*Impressa-clay* of Quenstedt), with *Terebratula impressa, Rostellaria bicarinata, Dysaster granulosus*, &c. Effingen, Geissberg, Baden, &c.
Birmenstorf beds, with *Rhynchonella lacunosa, Terebratula reticulata,* &c. Buchsiberg, near Oberbuchsiten; vineyards of Birmenstorf; Mandach; Villingen; Bötzen; Schinznach.

II. BROWN JURA.

UPPER BROWN JURASSIC STAGE.

CALLOVIAN.

Alpine Zone.

Chain of the Stockhorn.

Northern Zone.

Ornatus-clay. Reddish brown and yellow ferruginous clays with *Ammonites ornatus* (Oxford marls).
Macrocephalus-beds. Elfingen, &c. (Kelloway rock).
Discoidea-marls, with *Holectypus depressus.* Kienberg, Frick, Hornussen, Bötzen, Liesthal, &c. (Cornbrash).

MIDDLE BROWN JURASSIC STAGE.

BATH OOLITE.

Alpine Zone.

Ferruginous Oolite from the Canton of Vaud to the Glärnisch.
Beds of Oberlegli.

Northern Zone.

Ferruginous-clay Oolite.

Great Oolite. Wasserfluh, Staffelegg, Winterhalde, Prattelerhorn, Sissacherfluh, Hühnersedel, Farnsberg, Thiersteinberg.
Lower ferruginous Oolite or *Humphriesianus-beds.* Betznau, Hornussen; eastern slope of the valley of Ergolz.

LOWER BROWN JURASSIC STAGE.

BAIOCIAN.

Alpine Zone.

Chain of the Stockhorn.

Roc des Fares near Arveyes, district of Ollon, Bommerstein on the lake of Wallenstadt.

Northern Zone.

Beds with Ammonites Sowerbyi.

Murchisoniæ-beds; brown, ferruginous limestone with *Ammonites Murchisoniæ*. Schambelen upper strata, Frickberg, Betznau.

Opalinus-clays, with *Ammonites opalinus*. Schambelen upper strata, Sissacherfluh, &c.

I. BLACK JURA.

UPPER BLACK JURASSIC STAGE.

TOARCIAN.

Alpine Zone.

Piz Padella in the Engadine, Stockhorn, Hochmad, above Blumenstein, Bex.

Northern Zone.

Jurensis-marls, with *Ammonites jurensis* and *radians*.

Posidonia-shales, with *Estheria Bronnii* and *Belemnites paxillosus*. Schambelen, Betznau, Farnsberg (Boll).

MIDDLE AND LOWER BLACK JURASSIC STAGES.

LIAS AND SINEMURIAN.

Alpine Zone.

Bommerstein Magereu, Chain of the Stockhorn, neighbourhood of Bex.

MIDDLE BLACK JURASSIC STAGE.

LIAS.

Northern Zone.

Amaltheus-clays with *Ammonites amaltheus* and *costatus*. Frick, Gansingen, Staffelegg, &c.

Numismalis-marls, with *Terebatula numismalis*, *Gryphæa cymbium*, and *Pecten priscus*. Frick, Ittenthal.

LOWER BLACK JURASSIC STAGE.

SINEMURIAN.

Northern Zone.

Gryphite-limestone, with *Gryphæa arcuata* and *obliqua* and *Ammonites Bucklandi*. Schambelen, Prattelen, Arisdorf.

Insect-marls. Schambelen lower strata.

We have already noticed (pp. 124, 125) the great differences between the Alpine Jurassic limestone and the limestone of the North-western Jura. Fossils are very rare in the alpine limestone; and there is consequently a difficulty in classifying the massive rocks enclosing those ancient remains; but the two great divisions of the White Jura and the Brown Jura are determined.

The Brown Jura consists, for the most part, of a compact limestone, with granules of oxide of iron, which, when the stone is weathered, give a red colour to the soil, and also impart to the rock a red or brownish-red colour. The Brown Jura may be traced along the Alps from Gonzen, in the Canton of St. Gall, through the Cantons of Glaris, Uri, and Unterwalden, into the chain of the Stockhorn, and in the vicinity of Louëche, although that formation does not everywhere appear at the surface. In some places the iron so much predominates that the rock becomes an excellent iron-ore. The pits at Gonzen are in this ironstone. Iron-ore was also formerly worked on the Oberleglialp, in the Klönthal, above Golzern, on the Windgelle, and in the valleys of Gentel and Lauterbrunnen. The fossils found in the ironstone show that it belongs to the Brown Jura. The great walls of limestone which rise from the romantic alpine lake of Oberlegli (Canton of Glaris) contain numerous marine animals in a bed of ferruginous oolite, about 500 feet above the surface of the lake. From this locality Prof. Heer has obtained ten species, viz. six Ammonites—*A. Martinsii* (fig. 67), *A. Parkinsoni* (fig. 69), *A. Morrisi*, Oppel (fig. 68), *A. Bakeriæ*?, *A. hecticus* and *A. rectelobatus*, Hauer,—the *Ancyloceras annulatum* (Desh.), the *Pleurotomaria armata* (D'Orb.), an oyster (*Ostrea pectiniformis*, Quenst.), and the *Belemnites giganteus*, all animals characteristic of the Brown Jura. Other species have been obtained from the Stockhorn chain (see Studer, 'Geology of Switzerland,' ii. p. 44).

Careful comparison enables Professor Heer to recognize in the Alps the different stages of the Brown Jura. On the Bommerstein, near Mols, Professor Escher de la Linth and M. Mösch found *Ammonites opalinus* with *Estheria opalina*; and in a somewhat higher bed, similar to the *Opalinus*-clay of the Canton of

Aargau, they have met with *Gyrochorte comosa* and *Equisetum veronense*, Z. (?); the rocks of Fares, of Valeyre (near Montreux), and of Roche (between Villeneuve and Yvorne) in the Canton of Vaud, with their numerous remains of *Zoophycos*, represent the *Murchisoniæ*-beds; and the Ammonite-beds of the Oberleglialp correspond to the Great Bath Oolite[*]. Many beds of the Upper and Lower Brown Jura are represented in the chain of the Stockhorn.

The upper limestone of the high Alps is still poorer in fossils than the corresponding beds of the Brown Jura, although this stage is represented by very considerable chains of mountains extending from the lake of Wallenstadt to the upper part of the lake of Geneva, and forming a broad zone in the lower Valais. This limestone constitutes the chief mass of some of the largest Swiss mountains, such as the Mürtschen, the Glärnisch, the Tödi, the Glariden, the Scheerhorn, the Windgelle, the Titlis, the Wetterhorn, &c. However, in the Cantons of St. Gall, Glaris, Berne, and Vaud, some fossils have been found identical with those of the White Jura. Near Wallenstadt M. Escher de la Linth met with a coral-bank with *Astrææ*, *Nerineæ*, and *Diceras*, similar to those of the White Jura. On the Guppenalp, immediately above the Brown Jura, and beneath the alpine limestone, there is a limestone bed, in which M. Bachmann has discovered four Ammonites (*A. biplex*, *A. Henrici*, *A. tortisulcatus*, and *A. flex-*

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[*] M. J. Bachmann has demonstrated the occurrence, on the Oberleglialp, of *Humphriesianus*-beds and of those with *Ammonites Parkinsoni* (Great Oolite). To the former he refers the small-grained limestone which forms the perpendicular wall of the First to the south of the lake of Oberlegli, and the rocks below the perpendicular wall of the Glärnisch. At the First, he found *Rhynchonella spinosa*, Schl., *Pecten pumilus*, Goldf., and *Avicula tegulata*, Goldf.; at the Glärnischhalden, above Ruti, the *Ammonites Humphriesianus* is met with. The ferruginous oolite is much richer in fossils. Bachmann reckons forty-five species from the Oberlegli lake and at the Stafel of Guppenalp, among which are *Rhynchonella plicatella*, Sow., *R. spinosa*, Schl., *Terebratula Wirtembergica*, Oppel, *T. Mandelslohi*, Opp., *Myoconcha crassa*, Sow., *Lima pectiniformis*, Schl., *Pleurotomaria conoidea*, Desh., *Ammonites garantianus*, D'Orb., *A. subfurcatus*, *A. Parkinsoni*, Sow., *A. Wagneri*, Opp., *A. arbustigerus*, D'Orb., *A. Martinsi*, D'Orb., *A. Deslongchampsi*, Opp., *A. Morrisi*, Opp., *A. Ymir*, Opp., *A. Waterhousei*, Morr., *A. aspidoides*, Opp., *A. subradiatus*, D'Orb., *Nautilus clausus*, D'Orb., and *Belemnites canaliculatus*, Schl.

uosus), a Pentacrinite (*P. subteres*), and a *Rhynchonella* (*R. lacunosa*, var. *arolica*), which are characteristic of the strata of Birmenstorf. M. A. Escher de la Linth found, at the summit of the Schilt, *Ammonites arolicus*, Opp., *Aptychus lamellosus*, Park., *Belemnites hastatus* and *B. Sauvanasi*, and *Nulliporites hechingensis*, which characterize the beds of Birmenstorf. On the shores of the Lake of the Four Cantons, in the Oxfordian limestone, between Sissikon and the Tellsplatte, there is to be seen an oyster-bank containing numerous fossils—among others, *Ostrea hastellata*, Quenst., *O. gregaria*, Sow., *Gryphæa alligata*, Quenst., several *Terebratulæ*, and some remains of a cuttlefish (*Eleutheroteuthis helvetiæ*, Gieb.)*. In the chain of limestone-mountains which commence in the neighbourhood of Weissenburg, and extend to the Tower of Mayen and of Aï, before Yvorne, fossils have been found in various places (as, for instance, near the bridge of Wimmis, at the Pfadfluh, on the crest of the Wildenmann, and on the road of the Ormonts from Aigle to Sepey), which are completely analogous with species belonging to the upper White Jura. There is consequently no doubt that these limestone-mountains were formed during the Upper Jurassic period—although, in that district, the rare occurrence of fossils hardly permits their precise place to be determined or the different stages of the upper White Jura to be ascertained.

On the other hand the abundance of animals preserved in the rocks of the Jura properly so-called enables us to recognize the development of its different beds. An exact account of them is given in the General Table (pp. 152–154), which has been prepared from the researches of the Swiss Jurassic geologists, P. Merian, A. Gressly, C. Mösch, E. Desor, J. Thurmann, A. Müller, and F. Lang. Prof. Heer can only rapidly notice in this place the successive strata, and must refer those who desire more complete information as to the general position and organic contents of the rocks of the Swiss Jura to the works of the distinguished scientific writers here referred to†.

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* Giebel, 'Zeitschr. für die gesammten Naturwissenschaften,' 1860, p. 289 (On the Lake of the Four Cantons).

† P. Merian, 'Beiträge zur Geognosie.' Basle, 1821.

In the first place, there are three principal stages of the Jura, each of which, in its turn, consists of several subordinate or intermediate stages, differing one from another in the characteristics of the rock and in the organic remains contained in it.

Commencing with the Brown Jura, we find, at the bottom, the *Opalinus-clays*, so-called from an Ammonite (*Ammonites opalinus*, Quenst.), the shells of which are remarkably well preserved in the Jura of Swabia, where they still show their pearly lustre. This species, which, however, is scarcely distinguishable from *A. Murchisoniæ*, occurs, with *Ammonites torulosus* and *Estheria opalina*, Quenst., in the great marl-pits of upper Schambelen, the dark-coloured marls of which belong entirely to this subordinate stage. The same clay has been met with in the Cantons of Basle, Soleure, and Neuchâtel*, as well as on the Hauenstein, where it attains a thickness of 60 metres (or about 65½ yards). Its soft marls weather very readily, and not unfrequently give rise to dangerous landslips. Very few fossils are found in these clays. The following intermediate stage, on the contrary, contains an abundance of animal remains,

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A. Gressly, "Observations géologiques sur le Jura soleurois," Neue Denkschr. der schweiz. naturforsch. Gesellsch. ii. 1838, iv. 1840, v. 1841.

C. Mösch, "Das Flötzgebirge im Kanton Aargau," Denkschriften, xv. 1857. Verhandlungen der schweiz. naturf. Gesellsch. 1862, p. 156. Neujahrsblatt der Zürcher naturf. Gesellsch. für 1867.

E. Desor and A. Gressly, 'Études géologiques sur le Jura Neuchâtelois.' Neuchâtel, 1859.

J. Thurmann, "Lethæa bruntrutana, ou études paléontologiques et stratigraphiques sur le Jura bernois," Denkschriften, xviii. 1861, xix. 1862, xx. 1862.

Beiträge zur Geologie der Schweiz, herausgegeben von der geologischen Kommission. Erste Lief.: Der Kanton Basel, von Dr. A. Müller, 1863.

F. Lang, "Geologische Skizze der Umgebung von Solothurn," Schulprogramm pro 1863.

Prof. Heer has especially followed the admirable writings of M. Mösch, to whom he is equally indebted for many oral communications.

* In Neuchâtel the *Opalinus*-clay makes its appearance only in one place at the foot of Montperreux; but in the ideal sections prepared for the railroad of the industrial Jura, Desor and Gressly indicated both the *Opalinus*-clays and the Lias in the interior of the mountain. Their hypothesis was fully confirmed during the construction of the tunnel, and there is now no doubt that the Lower Brown and the Black Jura really exist in these localities.

among which the *Ammonites Murchisoniæ*, Sow. (fig. 65), has a wide distribution. Scallops also (especially *Pecten personatus*, Goldf.) lie by thousands in a brown sandy limestone, which weathers readily, and becomes converted into fertile soil. Here and there this limestone contains many nodules of clay-ironstone, from the size of a nut to that of the fist.

The Middle Brown Jura consists of the roestone or oolite, composed of innumerable spherical or lenticular calcareous corpuscles, which have been compared to the eggs of fishes, whence the name given to these rocks. In the oolite division, three subordinate stages may be distinguished; the upper and lower contain much iron, which gives them a dark or reddish-brown colour; these are the ferruginous oolites, which have been worked in many places for their minerals, as in the Lower Oolite near the baths of Bubendorf, and in the Upper Oolite near Sulz, where they furnish the Laufenburg iron.

Between these brown ferruginous oolites lies the white or yellowish-white *Great Oolite*, which includes the thickest deposits of the Brown Jura in Aargau and in Basle, and may be recognized even at a distance by its structure and colour. Commencing to the west of Mandach, it attains a very considerable thickness on the Wasserfluh and Staffelegg. In the Canton of Basle, according to Dr. Müller, it reaches a thickness of 150 metres (or about 164 yards); and here also it has its greatest horizontal extension, while it can be traced to a distance on the west. A peculiar charm is given to the landscape in the oolitic valleys of Basle by their yellowish limestone sides covered with verdant coppices, and varied by streams of water leaping down in gay cascades. The oolite mountains of the neighbouring districts of Aargau are remarkable for their rifted peaks resembling skittles or teeth.

The Great Oolite probably contains large quantities of comminuted fossils; but very few are well-preserved; the Lower Ferruginous Oolite, on the contrary, offers us an abundance of determinable animals, among which we may particularly notice *Belemnites giganteus*, *Ammonites Humphriesianus*, Quenst., several oysters (*O. Marshii*, *O. pectiniformis*, Quenst.), scallops and lampshells (*Pecten disciformis*, *Terebratula Meriani*, and *T. perovalis*). Of the marine plants, the large species of *Zoophycos* (fig. 92) is found in considerable quantity, and is also abundant in the *Murchisoniæ*-beds.

Notwithstanding the paucity of its well-preserved fossils, the period of the formation of the Swiss Great Oolite may be settled, as Prof. Heer has specimens of a number of species, such as *Ammonites Parkinsoni* (fig. 69), *Ostrea acuminata* (fig. 81), *Clypeus sinuatus* (Pl. IX. fig. 2), and *Cidaris Schmidlini*, Des., all of which are in good condition.

The first stage of the Upper Brown Jura consists of the blue or bluish-grey *Discoidea-marls*, which are not very thick (24–30 feet), but contain a great abundance of animal remains. Small beautifully preserved sea-urchins (especially *Holectypus depressus*, Pl. IX. fig. 5) occur in great quantities, and the shells of Mollusca are very numerous; but many of these (such as *Amm. Parkinsoni*, fig. 69, *A. discus*, fig. 64, *Ostrea Marshii*, and *O. acuminata*, fig. 81) have also previously appeared in the Middle Brown Jura.

The *Discoidea*-marls are followed by red and brownish-yellow sandy limestones, which weather into fertile soil, and in many places (as near Frick and the Hauenstein) furnish good building-stone, much esteemed for door- and window-sills. They contain in abundance a globular Ammonite (*A. macrocephalus*, Schl.), which sometimes attains the size of a small melon. From this fossil the deposit has received the name of the *Macrocephalus-beds*; these strata are variable throughout the whole Jura, and are of about the same thickness as the marls preceding them, with which they are closely allied.

The *Ornatus-marls* are widely spread; they consist of rather thin clay-beds, either of a reddish-brown colour or with yellow clay-nodules. The latter beds are full of remains of marine animals, often silicified, among which the beautiful *Ammonites ornatus* (fig. 71) is very plentiful; the *Amm. Jason* (fig. 70) and *Amm. Parkinsoni* are also met with, together with many other species. *Belemnites hastatus* appears in millions, and must have been conspicuous in the fauna of this epoch. M. Mösch found the remains of a crustacean in the shell of an Ammonite (*Amm. macrocephalus*), from which we may suppose that it took possession of this shell as a dwelling-place after the fashion of the hermit crabs.

The *White Jura* is divided into three subordinate stages, which are themselves subdivided into numerous beds, classified for the most part by M. Mösch.

The *Lower White Jura* commences with the *Birmenstorf beds*, which consist of pale ash-grey limestone deposits of no great thickness. In the vineyards of Birmenstorf and Auenstein, Hausen, and Schinznach, and on the heights of Hornussen, Bötzen, Elfingen, and in other localities, many well-preserved fossils are found, especially in spring, which have become detached from the rocks during the winter. The naturalist is pleased to meet with the *Rhynchonella lacunosa* (fig. 87) with its deep longitudinal furrows, the *Ammonites biplex* (fig. 66) with its forked ribs, the *Cidaris coronata* (Pl. IX. fig. 4), and numerous sponges and marine animals. In the upper Effingen bed the *Nulliporites hechingensis*, occurs, which composes the principal mass of the rocks. The Birmenstorf beds may be traced in the Cantons of Basle and Soleure (at Buchsiberg and Oberbuchsiten); and they appear again elsewhere, as, for instance, at the Randen.

The second subordinate stage of the Lower White Jura is formed by the *Effingen beds* (of Mösch), which consist of bluish-grey soft and much-fissured argillaceous limestones, alternating with hard rock masses, and containing disintegrated nodules. They may be traced from Schlossberg above Baden as far as the neighbourhood of Schinznach. At Effingen they reach a thickness of 300 feet. They furnish an excellent cement which is prepared from the argillaceous limestones near Aarau, Küttigen, and Mülligen. *Terebratula impressa* (fig. 88) occurs in these beds in great quantities; and from it this subordinate stage has received in Swabia the name of the *Impressa*-clay.

In the *Middle White Jura* there are three subordinate stages. The *Geissberg beds* (of Mösch) consist of a hard yellowish limestone, about 100 feet thick, which furnish an excellent building-material, and are therefore worked in many places. These beds are best seen in the perpendicular sides of the Geissberg, where they furnish many beautiful fossils; and fossils may also be collected in several quarries of Aargau (at Wildegg, Aarau, Gösgen, and Olten). Among the finest species are *Pholadomya paucicosta* (fig. 84), *Ph. cor*, Ag., *Ph. cingulata*, Ag., &c.,

Ostrea caprina, Mytilus amplus, Perna mytiloides, and *Pinna lanceolata.*

West of Olten, the rock becomes converted into bluish-grey marl; to the east, it does not extend beyond Kaiserstuhl.

The rocks of the following strata, "beds of *chailles,*" present quite different characters in Eastern and Western Switzerland.

At Porrentruy and Soleure, and in the western portion of the Canton of Basle, as far as the neighbourhood of Liestal, they consist of grey and often coarse sandy calcareous marls. In the upper part they alternate with layers of highly siliceous limestone nodules, as large as a man's head, called "chailles" in the French Jura. In the west of Switzerland this formation is about 100 feet thick, but it disappears entirely at the western boundaries of the Cantons of Basle and Aargau. A line drawn from Basle to Obergösgen indicates the limit at which these deposits of nodules are replaced by a variegated oolitic limestone, called by Mösch the *Crenularis-beds;* to the east, the chailles-beds do not extend beyond the Canton of Aargau, and at the Geissberg and the Ryfluh they are reduced to a thickness of 3–4 feet.

Not only the nature of the *Crenularis*-beds, but also their fauna is different in Eastern and Western Switzerland. About two dozen species, however, belong to both the Swiss regions, among which Professor Heer cites the *Hemicidaris crenularis,* Ag. (Pl. IX. fig. 6), a sea-urchin provided with long spines.

Both the eastern and western ranges of these strata are rich in fossils peculiar respectively to each formation. Corals (*Astræa* and *Lithodendron*) and a quantity of sea-urchins characterize the west; whilst in the east there are sponges and bivalves, and sea-urchins are not rare, but are represented by different species.

The *Caprimontana-beds* of Mösch seem to be a local deposit of the Jura of Aargau. They form limestone beds 26–30 feet thick, with intervening layers of argillaceous shale, overlying the *Crenularis*-beds, and furnish a valuable building-stone at the Ryfluh, and near Braunegg, Baden (Schadenmühle), and other places. They contain a great number of prickly spines as long as one's finger, belonging to a sea-urchin (*Rhabdocidaris caprimontana,* Des.).

Coralline limestone forms the most important subordinate stage of the Middle White Jura, and a difference exists between the formation in the east and the west of Switzerland. According to M. Mösch, the Argovian white limestone strata, 8 to 10 feet thick, of Würenlingen, and at the Ryfluh and the Geissberg, belong to this deposit. There is a great variation in the thickness of the coralline limestone, which is 100 metres (or 109 yards) thick to the west of Basle, whilst at Porrentruy it is 65 metres (or about 71 yards) thick; and in the Canton of Neuchâtel it is reduced to a thickness of 4 metres, or 4½ yards.

The *Upper White Jura* of Porrentruy is divided by Thurmann into three subordinate stages, named from the animals which are found in each group of strata. The lower beds he calls *Astartian*, from an *Astarte* (fig. 83); the second, *Strombian*, on account of a species of *Pteroceras* (*strombus*); and the third, *Virgulian*, from the large quantity of the *Exogyra virgula* (fig. 82) found there. M. Thurmann has demonstrated the slow transformations which the fauna underwent at this period.

The lowest or *Astartian* stage has, at Porrentruy, an average thickness of 78 metres, or about 85 yards. It consists of regularly stratified greyish limestones with interstratified marly beds.

The *Strombian* stage is composed of yellow limestone beds, alternating with beds of marl; it attains an average thickness of 51 metres, or nearly 56 yards.

The *Virgulian* strata, the total thickness of which is about the same, consists, at Porrentruy, of white and yellow, marly, stratified, calcareous beds; it there forms the highest deposit of the Jura.

These three subordinate stages of the Upper White Jura extend also over the chain of the Jura in the Cantons of Soleure, Neuchâtel, and Vaud, and by their bare, white or yellow, steeply inclined rocks, and dry and sterile slopes, give a special character to the landscape.

In Eastern Switzerland the Upper White Jura is of much less importance. The *Virgulian* is only slightly developed; but the *Astartian* is well represented. It corresponds, according to Mösch, to the upper division of the Astartian of the west, and presents a greyish-coloured bed only 8–12 inches thick, containing greenish nodules; in this bed have been found numerous *Terebratulæ* (*T. insignis*), *Gryphæa alligata*, a sea-urchin (*Cidaris suevica*), and a characteristic *Aptychus* (*A. lamellosus*).

To the lower Astartian strata probably belong the *Letzi beds* and the *Baden beds* of M. Mösch, which, like the lower stages of the White Jura, differ in many respects from the contemporaneous formations of Western Switzerland.

The *Letzi beds* appear on the Bötzberg as very fine-grained laminated limestones, resembling the lithographic stones of Solenhofen. In other places, as at Baden and Braunegg, they are full of Pentacrinites (*P. subteres*).

The *Baden beds* are found on the eastern slope of the Baden tunnel, near Endingen, near Rieden, in the Siggenthal, at Lägerberg, above Wettingen, and near Regensberg, where they are about 45 feet thick. They consist of a grey limestone, here and there containing much clay, which is readily washed out, by which means the rock acquires a cellular corroded appearance.

The *Wettingen* strata must be referred to the Strombian beds. They consist of white limestone, containing flint nodules, and are not unfrequently indented by crevices and hollow shafts. These strata contain sea-urchins with remarkably long spines (*Rhabdocidaris nobilis*, Münst., figured one half of the natural size, Pl. IX. fig. 1). Another species of sea-urchin (*R. princeps*, Des.) from the Lägern is still larger than this, its test being 5 inches in diameter.

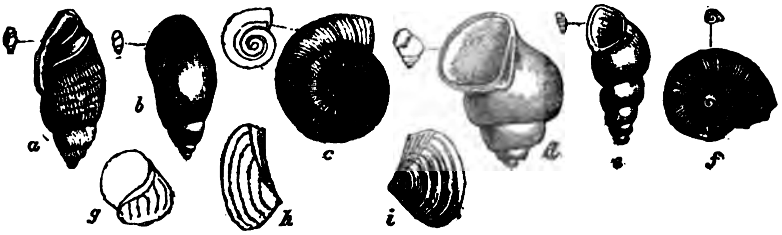
It is remarkable that in the Baden beds, side by side with species peculiar to them, we find others which also occur in the Lower White Jura, such as the *Rhynchonella lacunosa* and *Cidaris coronata*, which Professor Heer has frequently met with at the Lägern. Sponges also, such as *Scyphia obliqua* (fig. 62) and *Cnemidium Goldfussi* (fig. 63), are widely distributed here, very similar to those which the Professor has seen in the Birmenstorf beds.

A peculiar formation represents the transition from the deposits of the Jurassic period to those of the Cretaceous; it is produced by brackish water and fresh water. It has lately been discovered in the Swiss Jura, and presents a great analogy in its organic remains with the Purbeck beds in England. These freshwater strata complete the series of the Jurassic deposits.

and indicate that at this epoch the elevation of the country, which commenced during the White-Jura period, had raised the Jurassic zone of Western Switzerland above the level of the sea. It is only by the region being thus elevated that the presence of freshwater deposits can be explained.

The Purbeck has its greatest development at Villers-le-Lac (Doubs); but it seems to have extended over the whole Canton of Neuchâtel, and it has also been observed in French localities in that neighbourhood (Nantua). It consists of a calcareous marl of no great thickness, placed in conformable stratification between the upper stage of the Jura and the lower stage of the Cretaceous (Valangian). This deposit was first noticed in Switzerland by M. A. Jaccard; and M. P. de Loriol has described the fossils hitherto found in it*. Of the 26 species observed, 23 belong to the molluscan genera *Auricula, Carychium, Physa, Planorbis, Paludina, Bithynia, Valvata, Cerithium, Turritella, Neritina, Corbula, Cyrena, Cardium, Lithodomus,* and *Gervillia,* 2 to the Polythalamia (*Nonionina*), and 1 to the crustacean genus *Cypris*. They are all small species, and not at all remarkable; but some of them occur in great numbers. Fig. 97 B shows the principal forms.

Fig. 97 B.



a. Auricula Jaccardi, Lor.; *b, Carychium Brotianum,* Lor.; *c, Planorbis Loryi,* Coq.; *d, Paludina Sautieriana,* Lor.; *e, Bithynia Chopardiana,* Lor.; *f, Valvata helicoides,* Forbes; *g, Neritina valdiensis,* Röm.; *h, Corbula inflexa,* Röm.; *i, Cardium purbeckense,* Lor. The outline figures show the natural size; and the shaded figures are enlarged.

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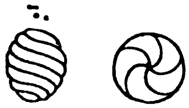
* See "Geological and Palæontological Researches into the Subcretaceous Freshwater Formation of the Jura, and particularly into the Strata of Villers-le-Lac," by P. de Loriol and A. Jaccard (Mém. Soc. de Phys. et d'Hist. Nat. de Genève, tome xviii.).

The genus *Auricula* is always met with on the sea-shore, and therefore announces the vicinity of the sea; this may be said also of the genera *Corbula, Cardium, Cerithium,* and *Turritella,* which live in brackish water and at the mouths of rivers. On the other hand, the species of the genera *Planorbis, Carychium, Physa, Paludina, Bithynia, Valvata,* and *Cyrena* are now only found in fresh water, and demonstrate the presence of fresh water during the Purbeck epoch.

To these animals must be added a plant, the *Chara Jaccardi,* the fruits of which (fig. 97 c) are met with in considerable quantities at Villers-le-Lac and also at the Gorge du Jorat, near Oroins. The genus *Chara* had already been observed in the Trias of Russia. In Switzerland it first appears in the Purbeck; and in later periods down to the present day it is well known. It is an articulated plant, with whorled branches, bearing oval or spherical fruits, of which the integument is composed of five threads twisted in a spiral form, giving it an elegant striated appearance. One species (*Chara Jaccardi*) has a very small fruit, of a short oval form and obtuse at the extremities; it consists of five folds rolled round into flattened spirals, and terminated by a more rapid turn. This *Chara* is also very common in the English Purbeck, which has, in common with the Swiss Purbeck, six species of Mollusca (namely *Physa wealdiana,* Coq., *P. Bristovi,* Forbes, *Paludina elongata,* Sow., *Valvata helicoides,* Forbes, *Corbula Forbesiana,* Lor., and *Cardium purbeckense,* Lor.) and one crustacean (*Cypris purbeckensis,* Forbes). In England the Purbeck is much more developed than it is in Switzerland; and in the English beds there have been found many Insects and some small Mammalia.

Fig. 97 c.



Chara Jaccardi, Heer.

This recapitulation of the stages and subordinate stages of the Swiss Jura shows that during the formation of these rocks great alterations took place in the deposits, as well as in the animals and plants which inhabited the Jurassic sea. A vast field of interesting study is still open to fix limits to the area of species in space and time. We find that many species occur only in particular beds, and therefore were only of short duration;

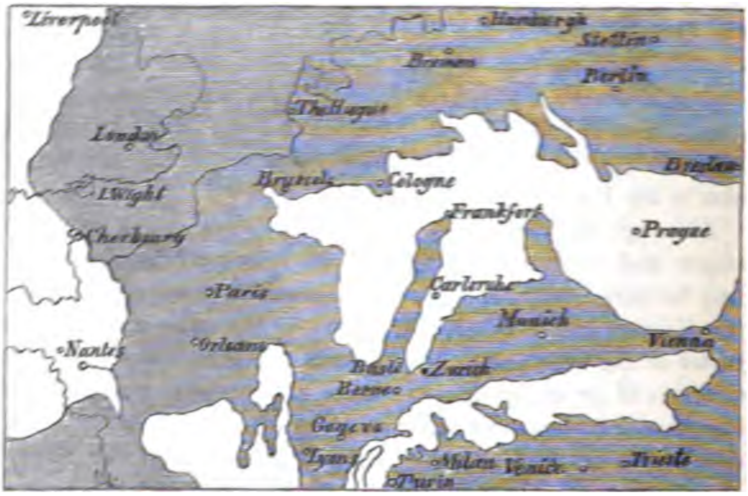
whilst others survived through several subordinate stages, or even through some principal stages. Thus the *Ostrea acuminata* and *Ammonites Parkinsoni* occur in the Middle Brown Jura as well as in the Upper Brown Jura, *Nerinea bruntrutana* (fig. 76) and *Pterocera oceani* (fig. 78) begin in the Coralline limestone and extend as far as the Strombian and Virgulian, and *Rhynchonella lacunosa* (fig. 87) and *Cidaris coronata* (Pl. IX. fig. 4) appear in great quantities both in the Lower and Upper White Jura. This is the case also with plants; the Nulliporites are by no means confined to the Birmenstorf beds, but are found also in the Upper White Jura.

Although throughout the whole Jurassic region the principal stages and most of the subordinate stages of the formation may be recognized, yet there is an essential difference between the Eastern and Western Jura, both in the mineralogical character of the beds and in their faunas. We have seen that the Oolite is of great thickness in Basle and Aargau, but loses its importance further west, and disappears in the east near Mandach—that in the Cantons of Aargau and Basle the character of the landscape depends on the Brown Jura, and in western Switzerland the landscape is determined by the White Jura. It is, however, worthy of notice that both the Lias and the Brown Jura of the whole of Switzerland, and also of the neighbouring parts of France (as, for instance, near Salins), show a complete identity in their fossils with the formations of the same age in Swabia; whilst in the White Jura this agreement extends only to the Cantons of Schaffhausen and Aargau, but can no longer be traced further to the westward. In the Cantons of Berne, Neuchâtel, and Vaud, and the neighbouring parts of France, the White Jura acquires so different a character that it is difficult to ascertain the contemporaneous formations. Professor Heer is of opinion that the configuration of the land in the Jurassic age has occasioned this characteristic difference.

The regions of the Black Forest and of the Central Alps have been already noticed: we will now endeavour to determine their form during the Jurassic period. Assistance will be derived from the map (fig. 97) on the next page.

The land of the Black Forest extended into Switzerland as a broad strip of Trias from Basle to Klingnau, forming the southern extremity of the continent, which on the east was bounded by the Wuttach. To this strip of land Prof. Heer has already given the name of *Odinland* (p. 91). It occupied a great part of Wirtemberg and Baden, and also extended over eastern France as far as the Moselle; in Alsace it had been previously penetrated by a gulf of the sea. Until the time of the Middle Jura this district was probably connected with the continent, and formed an important part of Central Europe, being at that time a southern cape*.

Fig. 97.



Central Europe in the Jurassic period. The continents are white; the shaded parts represent the sea.

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* At the time of the Lias and the Brown Jura there was probably a wide inlet of the Alsatian gulf in the Odinland, near the Black Forest. Prof. Fraas supposes (see Deffner and Fraas, "On the depression of Langenbrücken," Wirtemb. Annual) that the sea extended from Langenbrücken as far as Swabia; so that the land of the Black Forest would then have been separated from the continent. Near Langenbrücken, in Baden, there is a marine formation which contains all the deposits from the bone-bed to the Upper Brown Jura (the *Murchisoniæ*-beds) exactly as in Swabia, from which Fraas

In Switzerland the chain of the Central Alps, consisting of crystalline rocks, was dry land, as upon it there are no Jurassic marine deposits, although here and there doubtless some lagoons stretched into that Alpine island. The Jurassic sea, which covered a great part of France and penetrated into Switzerland along the whole boundary which now separates the two countries, probably filled the basin between the Odinland and the island of the Alpine group, and was connected with the eastern sea which covered a great part of Bavaria and the south and east of Swabia.

As the Odinland extends furthest towards the south between Basle and Lauffenburg, and opposite the Odinland promontory the Alpine island (from the Wetterhorn to the Reuss) advances more towards the north, this marine portion evidently forms the narrowest part in the whole basin of the Jurassic sea, and may be regarded as a strait. It is very remarkable that in this locality the Brown Jura of the Canton of Aargau attains its greatest development, and *is not covered by the White Jura*; so that at the time of the White Jura the Brown Jura was probably already dry, and must on that account have rendered the strait still narrower. The arm of the sea was barred, at least on the Swiss side, during the Oolitic formation; and perhaps the southern part of the strait was also sanded up; but the silting-up cannot be determined, as a more recent formation (the Molasse or Miocene) covers all the country.

The strait of the sea has probably given rise to the Oolitic

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concluded that there was a direct communication between the seas, although in the wide space from Langenbrücken to Reutlingen in Wirtemberg there are no marine formations, and therefore it must be assumed that they have all been washed away. It seems to Prof. Heer, however, much simpler to suppose that the Langenbrücken marine formation was produced in a bay of the Alsatian gulf. In all the Odinland the Liassic and Lower Jurassic formations show a great agreement; and the analogy may be seen by a comparison of the Lower Lias of Langenbrücken with that of Schambelen; hence it cannot be a subject of surprise to find that there was a similar analogy in the Swabian sea. But if the Alsatian gulf communicated with the Swabian sea, such a marine passage did not continue beyond the period of the Brown Jura, since at the time of the White Jura the land of the Black Forest was reunited to that of the forest of Odin.

beds in this locality. The Oolite contains very few well preserved fossils, but innumerable fragments of organic bodies, some beds consisting almost entirely of the débris of rolled and comminuted marine animals. Evidence is thus afforded of a shore-formation which has taken place near a much-agitated sea, such as might be expected in such an oceanic strait which formerly united two great seas. To the marine agency there must be added the waters flowing from the land and pouring into the sea sand-grains, around which lime was deposited; and thus all the elements are complete for the explanation of the oolitic formation. Let us not, however, overlook the fact that, although oolite is most developed in this region, it occurs also here and there in the White Jura, under the form of nests, as in the Coralline Limestone of Porrentruy and in Swabia, and that similar formations are produced at the present day in the coral islands.

If the eastern Jurassic sea was separated from the western sea by this strait, and by its subsequent sanding-up or partial filling, the reason is discovered for a somewhat different development of organic nature in the east and in the west during the White-Jura period, and for the Swiss western Jura so closely resembling the French, whilst the Swiss eastern Jura resembles the Swabian Jura. The line of demarcation, we see, falls exactly upon this sea-strait.

Let us, further, consider that during the formation of the White Jura an elevation, advancing towards the west, must have taken place in the region of the eastern Jurassic sea. The latest and uppermost Jurassic beds are deficient in Germany, and the Cretaceous formation is also absent from the whole of Swabia and over a great part of South Germany. But it is also wanting in the whole of the eastern Jura, the Canton of Schaffhausen, on the Lägern, and in Aargau; and Cretaceous beds commence at Bienne, from which place they can be traced westward in several bands where we find the lower Cretaceous stages—the upper ones, as well as the whole of the Nummulitic and Flysch formations, so important in the Alps, being entirely wanting in the region of the Jura. During the time of the White Jura, the upheaval advanced in a direction from east to west. As early as the time of the formation of the calcareous slates of Solenhofen and Nusplingen (which belong to the Upper

White Jura) the Swabian sea became smaller; and at the end of the Jurassic epoch the sea to the east of the Odinland entirely disappeared, and the land in consequence increased in size. During the earlier Cretaceous period the land was still further enlarged by the gradual retreat westward of the western sea; and at the epoch of the Upper Cretaceous formation even the whole western Jura had become dry land.

Coral beds prove that while there was a gradual and slow upheaval of the whole of the Swiss and Swabian Jura from east to west, portions of the range were subjected to depressions from time to time; thus, near Porrentruy, the lowest coral beds are covered by limestone rocks about 500 feet thick, belonging to the Upper White Jura (Astartian, Strombian, and Virgulian). At the time of the formation of the Coralline limestone, the coral beds were very probably only 100 to 200 feet under water, as the coral-polypes cannot live at greater depths. Here, therefore, a gradual depression must have taken place, in consequence of which the animals reaching greater depths died off, whilst the polypes in shallower water continued to build on the reefs, until their development was arrested by a mass of mud and sand, which put an end to their lives. Then the Astartes arrived in the locality; and afterwards the Corals appeared again (in the Astartian and Virgulian periods), and formed white calcareous beds.

In the limestone Alps the same alternations of level took place. During the Jurassic period there had been a gradual general upheaval, accompanied by wide-spread depressions of the ground. An island at the time of the Upper White Jura seems to have stretched from the neighbourhood of Aigle to the Lake of Thun; and in it the carboniferous shales are covered by purely marine limestone rocks which contain Corals (*Astræa* and *Anthophyta*), Sea-urchins, Oysters, Scallops, Muscles, and *Terebratulæ* of the latest Jurassic formation, proving that this island had been sunk below the level of the sea during the Jurassic epoch, and that in this manner the land on it, previously covered with forests, became occupied by a marine population.

Conditions of the existence of plants and animals must have been materially and often altered by varying configuration of land and sea, which led to changes in the direction of marine currents and in the nature of the gulfs or sea-basins, giving rise to gradual transformations of the marine fauna.

Deposits of the Jurassic sea have had a very important influence on the formation of Switzerland; but they contain few mineral treasures. *Iron*, as already stated (p. 155), occurs in the ferruginous oolite of the Brown Jura in sufficient quantity to have made it worth working. The most important deposit is that of Gonzen, which is situated on the south side of the mountain; it is from 4 to 20 feet thick, and is surrounded by a bluish-black limestone. The ore is a compact red ironstone, and in the upper division of the deposit, 4–5 feet thick, contains black manganese ore (psilomelane). Magnetic iron, carbonate of manganese, sulphate of barytes, fluorspar, and iron pyrites also occur; the pyrites rendered the extraction of the iron very difficult. The mines have been abandoned on account of the competition of English and Belgian iron.

A second product of the Jurassic epoch is *coal*, which, however, is so thin and so sparingly distributed that it is of but little importance. The Jurassic coal, as already mentioned (p. 146), occurs in South-western Switzerland, and is worked in the Canton of Berne, on both sides of the Klus, and on the northern slope of the Holzerfluh—also on the south side of the lake of Geneva, at the foot of the Cornettes, in the Valley of Abundance, and above Vouvry. According to Studer, the coal is shining black, in short laminæ and rich in bitumen; it forms little beds from 6 to 18 inches thick, or nests in a marl-slate, and in a sandy limestone of 20–30 metres thickness; this limestone immediately overlies the uppermost masses of the Lower White Jura.

Excellent building-stones are furnished by the Upper White Jura. The limestones of Soleure are especially celebrated, and are exported to considerable distances; and in the Cantons of Neuchâtel, Berne, and Aargau there are numerous quarries. Most of these quarries in Aargau (at Aarau, Gösgen, Biberstein, Wildegg, Lauffohr, and Remigen) are in the Geissberg beds. The fine-grained laminæ of the Letzi beds of the Upper White Jura at Bötzberg are worked by M. Mösch as lithographic stones.

As the Upper White Jura consists of very hard rocks which do not readily weather, it generally forms a dry sterile soil, and its plateaux and slopes usually present a desert and bare aspect, while the Brown Jura, and still more the Lias, furnish a fertile soil in consequence of their numerous marly layers, which easily weather.

For tunnelling, however, the White Jura is far preferable to the Brown and Black, as is shown by a comparison of the great tunnels of the Jura railway with the Hauenstein tunnel. The former tunnels are cut in the White Jura, and only rest on the Lias in a few points, whilst the Hauenstein tunnel pierces the rough and great mass of soft stone of *Opalinus*-clay and of Lias, which not only offer great difficulties in the way of its construction, but also occasion much expense in the maintenance of the works.

CHAPTER V.

CRETACEOUS PERIOD.

To the Jurassic period succeeded the series of rocks to which the general name of *Cretaceous* has been given. Chalk constitutes the best-known product deposited in the period called *Cretaceous*.

In Germany chalk is found in the isle of Rügen, in Belgium near Maestricht, and in France in the environs of Marseilles and in Meudon; but it is wanting in Switzerland. The mass of Swiss rocks formed at this period chiefly consist of a hard and compact limestone, with strata here and there of marls, clays, and sandstones. The Swiss Cretaceous formations are marine. We have already seen (p. 165) that in Western Switzerland, at the close of the Jurassic period, a freshwater deposit of little thickness, but of considerable extent, was formed. At that time there must have occurred in Europe an important upheaval, so that the continents increased in size, and changes ensued in the distribution of land and water.

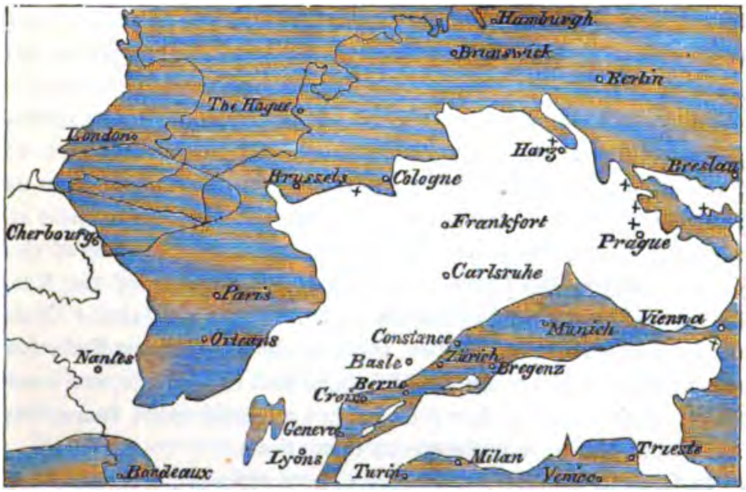
In Switzerland the whole Jura had probably become dry land, upon which fresh water could collect and serve as the dwelling-place of plants and animals. Only an arm of the sea remained along the line of the Alps; and there probably, in course of time, a marine equivalent of the freshwater formation will be discovered. After the Jurassic period a depression of the land again occurred; for the freshwater formation of the Western Jura is covered to a considerable depth by marine deposits.

No traces of Cretaceous rocks are found at Randen, Lägern, or in any part of the North-eastern Jura as far as the neighbourhood of Bienne; nor are there any Cretaceous remains in the border lands of France or Swabia. Hence a large increase of extent must have taken place in the districts of the Black

Forest and the Vosges, which became united together, forming a great Central-European continent, and confining the Swiss Cretaceous sea within a narrow channel, which was further limited by the Alpine (or Penninocarnic) island, on the sides of whose crystalline rocks rested a strip of Jurassic rocks not covered by the Cretaceous deposits.

The map (fig. 98) shows the distribution of land and sea in Central Europe at the Cretaceous period.

Fig. 98.



Central Europe during the Cretaceous period. The white portions represent continents; and the shaded parts are seas.

The changes which had taken place in the configuration of Switzerland after the Jurassic formation will be seen by a comparison of the Jurassic map (fig. 97, p. 168) with the Cretaceous map. Very little modification took place in the north of Germany, whilst the Central-European continent increased much in size towards the south and west, and the sea was kept back and separated into several basins. The Swiss sea was at that time continued through the present valley of the Rhone into the Mediterranean; but south-west of Geneva it was contracted into a strait; through Bavaria and Austria it was connected with the great eastern sea which spread over Hungary, Dalmatia, and Italy. A broad belt of land separated this sea from the Cretaceous sea occupying the east of England and the greater part of the north and west of France, and traversing the north of Germany so as to become united with the great eastern sea.

During the Cretaceous period, a great part of Switzerland was dry land, the sea covering chiefly the low ground from the Lake of Constance to the Lake of Geneva; its northern coast ran nearly in the direction from Schaffhausen by Aarau and Soleure to Bienne, and thence extended further westward, quitting the limits of Switzerland. The Cretaceous sea no doubt covered these districts, where strips of marine Cretaceous deposits are frequently met with, which were formerly connected together.

The southern shore of the Swiss Cretaceous sea is shown generally by a line drawn from the Lake of Wallenstadt to Altdorf, the Lake of Brienz, and Bex; but there are numerous and sometimes deep inlets bringing the sea into the interior of the Alps—for instance, towards the east, in the Canton of the Grisons, where the Calanda and part of the chain of the Kalfeusen are formed of Cretaceous rocks. From the lake of Thun to the neighbourhood of Bex these rocks appear but little (on the Stockhorn chain, on the Wildhorn and Oldenhorn, and near Bex); they probably, however, occupy a considerable space, but are covered over by more recent formations.

In front of the Cretaceous rocks lies a strip of purely Jurassic land, which probably formed an island in the Cretaceous sea, extending from the lake of Thun to the upper end of the lake of Geneva. As the Moléson is situated in the middle of it, we may call it the Moléson island. A second large island is formed by the belt of Jurassic limestone not covered by Cretaceous deposits, which extends from Uri by Glaris to the Lake of Wallenstadt, and is connected with the sernifit rocks there. These two long and narrow Jurassic islands stretched along the shore of the Cretaceous formation.

In the Cantons of St. Gall, Appenzell, Glaris, Schwyz, and Unterwalden, the whole chain of the Sentis, of the picturesque Kurfürsten, and the Wiggis, and the magnificent mountains which surround the Lake of Uri, and generally the southern part of the Lake of the Four Cantons, consist of marine deposits of the Cretaceous period.

Considering the great amount of dry land existing in Switzerland at this period, it is very singular that we know none of the land plants and animals which inhabited the country. No doubt there were lakes at that time, and in their mud organic bodies were deposited; but either these deposits have at some later time been washed away or they are still concealed from us. But when we turn to the sea, we find an abundance of animal life. At the first glance we fancy we have before us many forms known to us from the Jurassic sea—many Ammonites, *Nautili*, and Belemnites, and whole masses of bivalve and univalve shells, sea-urchins, and corals, which for the most part belong to the same genera as those of the Jurassic period. But if we examine them more closely we soon find that throughout the species are distinct from their Jurassic predecessors. Many, indeed, are so near that they are probably descendants of the Jurassic species; others, however, present new forms; and many of these depart so widely from those of the preceding period as to represent peculiar genera (e.g. *Toxaster, Micraster, Pilula, Ananchites, Baculites, Turrilites, Ptychoceras, Hamulina*, &c. &c.) or even families (*e.g.* the Rudista), and convince us that, after the Jurassic epoch, *a transformation of the whole of organic nature* had taken place.

We find ourselves in a new age embracing a long period of time, during which nature, never resting, laboured incessantly in the building-up of the solid crust of the earth, as well as in the transmutation of organic forms.

Professor Heer has divided the Swiss Cretaceous period into several stages, of which the Table is given in the next page (p. 178).

These different stages of the Swiss Cretaceous formation are distinguished both by the nature of their rocks and by the organic remains which they contain. In the Alpine zone the Cretaceous strata are very different from the Cretaceous beds in the Jurassic zone; and consequently the deposits of the two shores which enclosed the Swiss Cretaceous sea differ from each other in the same way as was the case with the deposits on the two corresponding shores during the Jurassic period.

TABLE OF THE SWISS CRETACEOUS FORMATION.

Stages.	Cretaceous of the Alps.	Cretaceous of the Jura.
Upper Cretaceous.		
10. Danian ...... 9. Senonian...... 8. Turonian...... 7. Cénomanian ..	Seewen limestone. Fitznauerstock, Seewen, summit of the Mythen, Rautispitz, Obersee, Kurfürsten, chain of the Sentis.	7. Mouille - Mougnon, near St. Croix, Col de Cheville.
Middle Cretaceous.		
6. Gault (Albien, D'Orb.)	Southern borders of the lake of Geneva, Unterwald, Calanda, Vettis, Leistkamm, Kurfürten, as far as the Sentis.	Perte-du-Rhône, St. Croix, Lake of Saint-Point, Saint-Immerthal, Col de Cheville (lower bed).
Lower Cretaceous.		
5. Aptian..........	From Mont Pilate to the Kurfürsten and the Sentis.	Perte-du-Rhône, St. Croix, Reculet.
4. Urgonian (Schratten limestone, *Rudista*-limestone).	Dent-du-Midi, environs of Bex, Rawyl-Abendberg, Hohgant, Schafmatt and Schrattenalp in the Entlibuch, Pilate, mountains of Lake Uri, Rauti, Wallenberg, Ammon, Kurfürsten, Wildkirchli, Meglisalp.	Perte-du-Rhône, La Sarraz, Orbe, St. Croix, Val-Travers.
3. Neocomian (so called from Neocom, Neuchâtel), or *Spatangus*-limestone.	Chablais and Faucigny, chain of the Voirons, Châtel St. Denis, south declivity of the Stockhorn, ridge of Brienz, Merlingen, environs of the Lake of the Four Cantons, upper part of the Glärnisch, Wiggis, Kurfürsten, Sentis.	Salève, St. Croix, Neuchâtel.
2. Valangian	On the Glärnisch, foot of Mont Pilate, Kurfürsten, Sentis.	St. Croix, Val-Travers.
1. Wealden?	....	Freshwater formation of Villars le lac, near the Brenets, at Jougne, Morteau, and Charix.

Beginning with the lower strata, Cretaceous rocks of the Swiss Alps which belong to the *Valangian* stage consist of a dark, hard, siliceous and sometimes oolitic limestone, as on the Sentis and Glärnisch. In the Jurassic region, the Valangian consists of bluish-grey marls and limestones, here and there containing an oolitic ironstone. The compact limestone, which varies in colour from yellow to brown, encloses granules of iron-ore rarely larger in size than a grain of millet. Endeavours have been made to work this iron at various places (near Fourgs, Métabief, near St. Croix, and Rochejean), but without success.

The *Neocomian* of the Alps (*Spatangus*-limestone) is chiefly composed of dark grey or black hard marls, consisting, according to Studer, of an intimate mixture of lime, calcareous sand, and clay. Sometimes the sand predominates, and we find a green or dark-coloured sandstone; sometimes the lime, and a pale blue, easily weathered, shaly, and marly limestone, or a black impure limestone is produced. The *Neocomian* of the Jura, on the contrary, consists, in its lower part, of bluish grey marls, becoming yellowish above, which readily break up on exposure to the air, and are used as manure; in its upper part it forms a compact and generally yellow limestone. The upper beds furnish an excellent building-stone, distinguished by its fine grain and beautiful pale yellow colour. Neuchâtel is built of this stone, which gives it a peculiar character. Hence the name given to the deposits of this stage has been justly derived from that of the city of Neuchâtel (anciently called Neocom). The ruins of the ancient Aventicum prove that this stone was used for building by the Romans.

The *Urgonian* (*Schratten* limestone) is very widespread in the Alps. It is distinguished from the Neocomian by its lighter colour, and forms rocky walls often several hundred feet high, which here and there have remarkable fissures (*Schratten*), as upon the Schafmatt, on the Schrattenalp, in the Entlibuch, and on the Silber, and behind the Glärnisch. The hard white limestone is traversed by innumerable channels, which are united so as to form a perfect labyrinth, and are often separated from each other by ridges as sharp as a knife. From this remarkable structure the rock has received the name of "Schratten limestone." The channels have probably been formed in the course of ages by the action of water, the soft constituents of the rock having been gradually dissolved and washed away, whilst the hard parts have remained and formed the ridges. Here and there one sees thick shells of Mollusca projecting from the rock, and producing figures of a darker hue on the greyish white limestone.

In the Jura, the Urgonian consists of a white, generally compact rock, which often acquires a yellowish colour, and is not easily distinguished from the Neocomian; or it is pale grey, and then resembles the uppermost Jura. In some places the Urgonian furnishes a fine building-stone, and in other places it contains asphalte, which in the Val-Travers (between Couvet and Travers) has been worked for many years. A similar asphalt-deposit occurs at the Perte-du-Rhône in a higher stage of the Cretaceous (the Gault), whilst the asphalt of Seyssel, of Pyrimont, and of Chavaroche au Fier (a league west of Annecy) is found in the White Urgonian limestone. In the neighbourhood of Geneva, and in Savoy, the differences between the Alpine and Jurassic Urgonian limestone disappear.

At the Perte-du-Rhône, in the Jurassic district, the Urgonian is overlain by the *Aptian,* which consists of yellow marly limestone and sandy grey and yellow marls. In the Alps the Aptian occurs, but its light-coloured limestones cannot be distinguished from the Urgonian.

Gault is characterized by its dark colour, and forms the dark bands which stand out so clearly from the paler rock of the Swiss Cretaceous mountains. It consists of green or black sandstones and limestones, containing a great quantity of green grains, whence it derives the name of Greensand. These green grains consist of a silicate of protoxide of iron; and their oxidation causes the dark colour of the rock. Here and there the greensand contains numerous nodules, probably consisting of phosphate of lime (as on the Wallenberg, near the bridge of Mollis, and on the Plattenalp). They are identical with the phosphatic nodules which occur abundantly at Farnham, in the county of Surrey, England, and are worked on a large scale for agricultural purposes.

In the Alpine zone, Gault is most developed in Eastern Switzerland, especially in the region of the Sentis, at the Lake of Wallenstadt, at Pragel, near Seewen, and is continued to Unterwald; but it does not appear in the Alps of Lucerne and Berne. It is again seen in the valley of the Rhone, and is largely developed in Savoy. At the Perte-du-Rhône it is a pale green sandstone, as also near St. Croix in the Jura, where it passes into a brownish-yellow marly limestone, and is covered by blue clay.

Of the *Seewen* limestone the best example is furnished by the limestone walls which rise from the pretty lake of Lowerz to the west of Seewen. It is a compact limestone, of a pale or dark grey colour, with a flat conchoidal fracture. Here and there it contains veins of flint. It is wanting in the Jura, but largely developed in the eastern Alps, forming the summits of the Mythen and the uppermost layer of the Oberseealp and of Rauti, and spreading over the Neueckkamm, the Leistkamm, the Kurfürsten, and the mountains of Appenzell, in which it crowns nearly all the highest peaks.

From this summary we see that the northern coast of the Swiss Cretaceous sea differs considerably in its deposits from the southern (Alpine) shore; but green grains occur in both shores: they are found in the Neocomian, are entirely wanting in the Schratten limestone, are again seen in great quantity in the Gault, and disappear in the Seewen limestone. As some of these green grains appear everywhere in the Cretaceous system, and especially in the Gault of England, we must assume a general cause for their formation and disappearance. There must have been, at two different periods in the Cretaceous epoch, an abundant supply of iron proceeding from the interior of the earth, and extending over a great part of Europe; but, for the present, we are not in a position to account for this phenomenon.

The difference in the constitution of the deposits on the

Alpine and Jurassic coasts need not surprise us. Their materials must in each case have come from the land. The streams which poured from the Alpine island into the Cretaceous sea assisted in the formation of the southern shore, conveying sand to it from the crystalline region for the production of sandstones. From the sides of the Jurassic mountains the streams brought down lime for the formation of limestone.

The darker colour of the Alpine Neocomian is probably due to the dark hue of the lower limestones of the high mountains, which must have aided more or less in forming these deposits; more recent sedimentary rocks were of lighter colour, and resembled the deposits of the Jura. The Gault is the only exception, and has its own dark colour from the oxidation of its ferruginous grains.

The brooks and rivers which flowed into the Swiss Cretaceous sea from the north coast came from a land comprising Jurassic deposits, but which, at a distance from the shore, was composed of all the older formations. A great granitic band made a country of mountains in the Black Forest and the Vosges, where the streams probably took their rise; this was surrounded by deposits of various kinds, which had been formed during the Triassic and Jurassic periods; and the rivers flowing over this region probably exerted a great influence on the calcareous deposits of the Jura in the Cretaceous period, and aided in giving a light colour to these Cretaceous strata.

The difference between the north and south coasts of the Swiss Cretaceous sea is shown by the marine animals buried in them, although the character of the fauna is nearly the same, and many similar species occur on both the shores. In this respect, the distribution of the Cephalopods in the Swiss Cretaceous sea is particularly instructive. They were animals able to move about in the depths of the sea, and therefore less than others confined to a given locality. Their distribution gives us important information as to the nature and extent of the Cretaceous sea.

The following Table comprises a summary of the species of Cretaceous Cephalopods observed in Switzerland.

TABLE OF SWISS CRETACEOUS CEPHALOPODS*.

Genera.	Number of Species.			Common to the Jura and the Alps.	Common to the sea of the South of France.			Common to the Franco-Britannic sea.		
	Switzerland.	Jura.	Alps.		Switzerland.	Jura.	Alps.	Switzerland.	Jura.	Alps.
Belemnites	16	8	16	8	13	8	13	5	2	5
Rhynchoteuthis	5	1	4	—	—	—	—	—	—	—
Ommastrephes	1	—	1	—	—	—	—	—	—	—
Nautilus............	21	13	16	8	12	9	8	13	10	11
Ammonites	131	80	112	61	104	60	97	44	34	36
Scaphites	6	4	5	3	3	2	3	3	2	2
Crioceras	2	2	1	1	1	1	1	—	—	—
Ancyloceras	39	4	35	(?1)	23	(?1)	23	3	1	3
Toxoceras	3	1	2	—	—	—	—	—	—	—
Anisoceras..........	6	6	2	2	4	4	2	3	3	1
Hamites............	20	15	14	9	11	11	7	10	9	8
Hamulina	3	—	3	—	2	—	2	—	—	—
Ptychoceras	6	1	6	1	4	1	4	—	—	—
Baculites	6	3	5	2	3	2	3	2	2	2
Helicoceras	2	2	1	1	2	2	1	—	—	—
Turrilites	18	16	12	10	15	13	11	5	5	4
	285	156	235	106	197	114	175	88	68	72

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* In preparing this Table, Prof. Heer has consulted the following works:—

F. J. Pictet, 'Mollusques fossiles qui se trouvent dans les Grès verts des environs de Genève.' Geneva, 1847.

F. J. Pictet et E. Renevier, 'Description des fossiles du Terrain Aptien de la Perte-du-Rhône et des environs de Sainte-Croix.' Geneva, 1854–58.

F. J. Pictet et P. de Loriol, 'Description des fossiles contenus dans le terrain Néocomien des Voirons.' Geneva, 1858.

F. J. Pictet et G. Campiche, 'Description des fossiles du terrain Crétacé de Sainte-Croix.' 1858–63.

W. A. Ooster, "Catalogue des Céphalopodes fossiles des Alpes Suisses," Neue Denkschr. der naturf. Gesellsch. xvii. & xviii. 1860–61.

P. de Loriol, 'Description des Animaux invertébrés fossiles contenus dans l'étage Néocomien moyen du Mont Salève.' Geneva, 1861.

This list of fossil Cephalopods has been enriched by M. Karl Meyer with the addition of the species in the public Museum at Zurich, collected in great numbers in the Swiss Alps by M. Escher de la Linth, and named by M. Mayer. It is not possible, just now, to extend the list to other classes of animals in the Swiss Cretaceous sea, as they have not been studied with the same care as the Cephalopods.

We have already seen that in Jurassic times the Alpine sea only presented in certain places a rich fauna, whilst the shallow sea of the northern zone was inhabited by an abundance of animals. A different state of things characterized the Cretaceous sea. The Table (p. 183) shows that the southern or Alpine zone presents the same multiplicity of zoological forms as the northern or Jurassic zone; indeed the Alpine zone considerably exceeds it in the number of species. This may partly be due to the fact that the Jurassic zone is only accessible to inquirers from Bienne to Geneva and at the Perte-du-Rhône, being concealed further eastward by more recent formations; whilst the Alpine zone may be traced from the upper valley of the Rhine to the Canton of Vaud and Savoy, and therefore presents many more localities for exploration*. There is no doubt, however, that the Swiss Cretaceous sea possessed as rich and varied a fauna on its southern shore as on its northern coast, and that in the Cretaceous period more favourable conditions prevailed for the colonization of animals.

The tabular summary of the Cephalopods of the Swiss Cretataceous sea shows that between one half and one third of the species are common to the Alpine and Jurassic shores; and it is worthy of notice that of the species of the Jurassic coast, two thirds appear also in the Alps. Of the Alpine species, however, scarcely one half have been detected in the Cretaceous beds of the Jura; but this is due only to the fact that the Jurassic fauna is poorer than that of the Alpine deposits. It may be objected to this view that during the Cretaceous period great changes took place in the marine faunas, and that the species referred to in the Table did not live at the same time. Prof. Heer has therefore brought together the species according to the various Cretaceous stages, so as to show in what manner the species have been distributed in each of the stages.

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* The following important localities may be mentioned:—in the Appenzell Alps, the Fähnern, the Oehrli, the Altmann, and the Sentis, on the summit of which large Ammonites have been found; in the Canton of St. Gall, the Kurfürsten; in the Canton of Glaris, the Firenbänder and the Nebelkäppler of the Glärnisch; in the Canton of Schwyz, the Alp Käseren, the Forstberg, Pfannenstöckli, and Wannenalp; in the Canton of Berne, the Stockhorn chain, the Faulhorn, the neighbourhood of Merlingen, the Justi valley, and the Hohgant; in the Canton of Fribourg, Châtel-St.-Denis; in the Canton of Vaud, Cheville and Anzeindaz. In the Jura the two principal localities are St. Croix and the Perte-du-Rhône. In the Canton of Neuchâtel there are several important deposits, of which Hauterive has long been known. In Savoy the best-known localities are Saxonet, the Voirons, Fix, and Sixt. These last belong to that part of the Cretaceous sea where it began to narrow into a gulf. Prof. Heer's description here comprises the mountains belonging to the basin of the lake of Geneva. The mountains of Savoy and of the south of France have been separately noticed by the Professor.

Table of Swiss Cephalopods in the different Stages of the Cretaceous Period.

Stages of the Cretaceous Period.	Number of Species.			Common to the Jura and the Alps.	Common to the southern French sea.			Common to the Franco-Britannic sea.		
	Switzerland.	Jura.	Alps.		Switzerland.	Jura.	Alps.	Switzerland.	Jura.	Alps.
Valangian	17	13	14	10	11	9	12	3	2	3
Neocomian..........	121	28	119	26	89	25	88	13	9	12
Aptian	27	12	23	8	25	11	22	12	8	10
Gault..............	110	105	76	71	59	58	52	49	49	42
Upper Cretaceous....	62	50	53	41	28	26	26	39	30	35

In the Valangian stage, the Cretaceous sea of the Jurassic coast had 10 species out of 13 in common with that of the Alpine shore, in the Neocomian 13 out of 14, in the Aptian 2 out of 3, in the Gault about 7 out of 10, and in the Upper Cretaceous 4 out of 5. This shows unmistakably that not only in the whole, but also in each subdivision of the Cretaceous series, the fauna of the Jurassic zone is very closely related to that of the Alpine zone, since it shares therewith most of its species.

But notwithstanding this close agreement of the species in the two zones, there is a difference in the development of their faunas, as will be demonstrated by a comparison of the Cephalopods of the Neocomian, Gault, and Upper Cretaceous stages.

In the Neocomian stage of the Alpine zone, Cephalopods are found in great quantities, comprising nearly all the species which occur in the Neocomian of the Jurassic zone, and containing altogether four times as many species as in the Neocomian stage of the Jura. Many of the Alpine species are peculiar and characteristic of the Neocomian stage.

The Neocomian fauna is especially characterized by the separate-whorled Ammonitidæ, represented in the Alpine region by 35 species of the genus *Ancyloceras*, most of which are wanting in the Jura; and even of the true Ammonites, many species specially belong to the southern or Alpine coast. We may therefore speak of the Swiss Neocomian stage as having a Jurassic and an Alpine fauna, each of which possesses a distinctive character. The Neocomian fauna of the Jurassic zone is found from Neuchâtel to the Salève; the fauna of the Alpine Neocomian may be traced along the chain of the Alps to Savoy, where the Voirons form its western limit.

In the Alpine zone 50 species of Ammonites are met with along the boundary of Eastern Switzerland as far as Savoy. Twenty of these species occur also in the fauna of the Jurassic zone, whilst 30 species belong exclusively to the southern coast. The numerous species of *Ancyloceras* which characterize the Alpine Cretaceous stage are almost exclusively confined to the Stockhorn chain, and do not pass Châtel-Saint-Denis: they are just as rare in the east of Switzerland (Kurfürsten and the Canton of Appenzell) as in the Jura. The fauna of Eastern Switzerland differs considerably from that of Western Switzerland in the Cretaceous sea. Of the 119 species of the Alpine Neocomian, 58 have not as yet been found in the east, and 11 are wanting in the west; so that, altogether, 69 species have not at present been observed on the southern coast line. That region of the Neocomian sea which stretched from the Stockhorn to the Canton of Vaud, and as far as the environs of Châtel-Saint-Denis, was most favourable for the development of animals, and therefore presents us with the greatest number of species.

On referring to the Alpine Cretaceous region in the Cretaceous map (fig. 98, p. 175) two long islands will be seen lying off the coast of the Alpine Cretaceous land; these islands were probably united by sand-banks, and they thus enclosed a broad lagoon. In the part of the Canton of Berne formerly occupied by this lagoon, and protected from the waves, animal life was encouraged; a numerous and varied fauna settled there. Shut off by the islands, the fauna differed more from that of the northern shore than the distance which separated the two localities would seem to have warranted.

The whole zone of the Jura probably became dry land at the close of the Jurassic period, whilst the deeper Alpine sea continued to be a centre of marine life. Afterwards, as the land again sank and the sea spread once more over the Jurassic regions and formed the Valangian and Neocomian deposits, the new population probably migrated to the Jurassic region from the Alpine sea. It is thus that we may explain the remarkable circumstance that, with the exception of two species, the Neocomian of the Jurassic shore only contains Cephalopods of the Alpine zone. Merely a part of the species belonging to the Alpine zone migrated towards the west (the Jurassic shore); whilst others, and especially most of those with separate whorls, remained behind in their native Alpine waters.

Probably the nature of the Alpine marine soil may have more aided in the development of these animals than the sea-bottom of the Jurassic or north-western coast. But these Cephalopods did not extend much towards the east; and hence the faunas of the Kurfürsten and of Appenzell have a great analogy with the fauna of St. Croix.

If the presence of many unrolled Ammonitidæ be regarded as a leading characteristic of the Alpine fauna, this character disappears in Eastern Switzerland as well as in the Jurassic zone, whilst towards the south it may be traced through Savoy and the south of France into Italy.

At the point where the Cretaceous sea narrowed into a strait, there is a mixture of the two faunas: thus the Swiss Jurassic-zone fauna is accompanied by the Alpine-zone fauna. In an upper bed the ancient character of the Jurassic fauna reappears, showing that the previous Jurassic series is repeated. This has been indicated by Lory in the neighbourhood of

Grenoble*, and shows us clearly that these two faunas have belonged to the same period, and that the differences observed were merely caused by local circumstances.

It is remarkable that the Salève in its Neocomian fauna shows the Jurassic character, whilst the opposite Voirons manifest Alpine characteristics; and the difference is thus obvious on the two coasts, which are so close together that we should have expected uniformity. The conditions of life must therefore have been different on the two coasts; and this may have been due either to the different nature of the shores or to marine currents. The western shore was probably shallower than the eastern, as seems to be indicated by the abundance of Bryozoa, zoophytes, and bivalves which occur in the Salève: the Voirons are remarkable for their Cephalopods. Perhaps there may be some difference in the age of the two deposits, although undoubtedly both belong to the same Cretaceous stage. If we suppose that in the Neocomian period the deposits of the Salève were formed at the time when, in Grenoble, the assemblage of species agreed with that of the Jurassic zone, and those of the Voirons a little later, and contemporaneously with the occurrence at Grenoble of a fauna including many Ammonites, the mystery is solved, without any necessity for assuming that the two sides of so narrow a gulf presented such great differences at the same time.

In the *Urgonian* stage the Cephalopods have almost entirely disappeared from the Swiss Cretaceous sea, and the *Aptian* also contains but few of them; whilst in the *Gault* they are almost as richly developed as in the Neocomian, and therefore furnish important materials towards a comparison of the faunas of the two shores of the Swiss Cretaceous sea. But the proportions are here changed: in the Jura the Gault possesses nearly four times as many species as the Neocomian, and in the Alps fewer;

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* Lory, "Esquisse d'une Carte Géologique du Dauphiné," Bull. Soc. Géol. de la France, tome xv. 1857–58, p. 32. In this district Lory distinguished 6 beds in the Neocomian: in Nos. 1, 4, and 5 the Cephalopods predominated; and Lory refers them to the Alpine character, and the beds 2, 3, and 6 to the Jurassic character, where bivalves and sea-urchins predominated. Nevertheless most of the Cephalopods cited by Lory occur also in the Jurassic zone, and several of the bivalves and sea-urchins are met with in the Alps.

so that the Jurassic Gault presents more species than the Alpine, whilst the Alpine Neocomian comprised more fossil species than the Jurassic Neocomian. Of the Gault, 71 Alpine species also occur in the Jura, manifesting the near affinity of the faunas of the two coasts. Only 5 species belong exclusively to the Alpine zone, and 34 to the Jurassic. It is remarkable that the genus *Ancyloceras*, which was so abundant in the western Alpine Neocomian, does not appear in the Alpine Gault, whilst three new species of that genus occur in the Gault of Sainte-Croix.

In the *Upper Cretaceous* the Cephalopods of the two shores show a close agreement. The number of species is nearly equal; and most of them are distributed on both coasts.

Hitherto we have referred only to the distribution of animal life in the Cretaceous sea so far as it is shown by the Cephalopods of the Swiss basin. There is, however, another interesting question—namely, In what relation did the Swiss fauna stand to those of the surrounding Cretaceous seas?

If the distribution of land and water has been correctly represented in Prof. Heer's map (fig. 98, p. 175), the Swiss fauna must necessarily have more species in common with that of the Southern French (or Mediterranean) than with that of the Franco-Britannic sea. And this is actually the case, furnishing an important confirmation of Prof. Heer's assumption that the Swiss Cretaceous sea was separated by land from the Paris basin. The Swiss Cretaceous sea has about two thirds of its species in common with the Southern French or Mediterranean sea, but scarcely one third with the sea which occupied the middle and north of France and the east of England. If we consider only the Ammonites, we find a similar proportion; three fourths of the Swiss species can be traced into the south of France, whilst only one third is common to the Franco-Britannic area; and the majority of these species occur also in north Germany, so that their distribution may be traced through Germany towards the Swiss sea. Thus we find *Ammonites varicosus*, Sow., *A. inflatus*, Sow. (fig. 120), *A. Bouchardianus*, D'Orb., *A. Delaruei*, D'Orb., *A. varicosus*, Sow., *A. rhotomagensis*, Br., *A. mammillatus*, Schl. (fig. 119), *A. Deluci*, Br., *A. Raulinianus*, D'Orb., *A. Renauxianus*, D'Orb., *A. splendens*, Sow., *A. Beudanti*, Br., *A. mayorianus*, D'Orb., *A. bidichotomus*, Leym., and *A. Carteroni*, D'Orb.,

in the Paris basin, in England, in North Germany, and on both coasts of the Swiss Cretaceous sea. They are widely distributed species, which also spread into the south-European sea. A much greater number of the Swiss species did not frequent the first-mentioned seas, and can only be traced to the limits of the southern French Cretaceous sea. That sea must, without doubt, have directly communicated with the Swiss Cretaceous sea.

A comparison of the two Swiss coast-faunas with those of the neighbouring seas shows that they both follow the same rule. Both have about two thirds of their species in common with the south of France; the Alpine zone has about one third, and the Jurassic nearly half of its species in common with the Franco-Britannic Cretaceous sea. The eastern part of the Alpine zone presents no exception; for out of 79 Ammonites of Eastern Switzerland, 67 occur also in the Cretaceous formations of the south of France. It is further remarkable that of the species which Switzerland shares with the South-French or Mediterranean basin, 16 have been discovered in Algeria (mostly near Constantine), and 6 (namely *A. mayorianus, tethys, pulchellus, Dydayanus, galeatus,* and *Hugardianus*) extend to the tropical regions of America.

Switzerland has 66 species in common with the German Cretaceous sea—a small number; but the greater part of the south German basin (which is to be regarded as an eastern continuation of the Swiss sea*) is concealed by more recent formations, and it has not been so carefully explored as Switzerland. As eight of the Swiss Ammonites have been observed in the Caucasus, we may see that they must have had a wide area of distribution.

On referring to the Table of the stages of the Swiss Cretaceous period (p. 185), we see that Switzerland, taking the *faunas of both coasts* during the older Cretaceous period, had a majority of species in common with the south of France, but only a few with the Franco-Britannic sea. Thus, out of 28 Neocomian species of the Jurassic zone, 25 occur in the south of France and only 9 in northern France, which proves that both the Alpine and Jurassic coast-faunas were more nearly allied to that of the Mediterranean basin than to that of the north-western sea. This applies also to the fauna of the Gault, although in a less degree, as the number of species in common with the north-western sea considerably increased; and it became still larger in the Upper Cretaceous stage. Prof. Heer knows almost as many species from the Upper Cretaceous of the Alps as from the Cenomanian of the Jura; and of these about one half belong also to the south of France, and rather more than half belong to the basin of Central and Northern France; so that the proportion is rendered quite different from that prevalent in the older Cretaceous stages.

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* The Cretaceous deposits of the Vorarlberg and of Bavaria are so like the Swiss that Prof. Heer cannot doubt their having been produced in a sea connected with that of Switzerland. See C. W. Gümbel, 'Geognostische Beschreibung des bayerischen Alpengebirges,' Gotha, 1861, p. 518, &c.

According to D'Orbigny, there were in France at the Neocomian period two large sea-basins, the Parisian and the Mediterranean, each possessing its peculiar fauna. Of 87 Mediterranean species, only 9 occur in the basin of Paris; consequently the same proportion existed as between the Swiss and Parisian seas. But subsequently, at the time of the formation of the Gault, the number of common species increased rather more than in Switzerland. Of 52 species of the Mediterranean basin, 27 occur also in the Parisian, which had in general become richer in species. D'Orbigny therefore supposes that, in consequence of great aqueous denudation, the land separating the two seas had been here and there broken through, so as to open communications between the two seas, which had been previously separated. It is probable that by denudation the land was broken through in a south-easterly direction, and also towards the basin of Bordeaux, and by this means both the Mediterranean and the Swiss seas acquired a larger number of species in common with the north-western sea. The investigations of Prof. Hébert upon the Paris basin are in accordance with this supposition, showing that from the Neocomian period onwards to that of the Upper Cretaceous the sea of the Paris basin increased in size, spreading towards the south and east, and then retreated within narrower limits in consequence of a gradual upheaval of the land.

The modifications of the fauna of the Swiss Cretaceous sea are of great significance with regard to the history of the development of the Swiss faunas, showing that in the same locality during the Cretaceous period profound alterations occurred both in the animal forms and in the intermixture of species. In this respect the fauna of Sainte-Croix in the Canton of Vaud, which has been investigated with great care by Dr. Campiche, and worked out in a masterly manner by Prof. Pictet, is most instructive. Here, within a narrow space, Prof. Heer meets with all the Cretaceous stages from the Valangian to the Cenomanian; so that when the animals of this locality are examined by his experienced eye, the changes are made manifest which occurred in that portion of the Cretaceous sea. At this spot thirteen strata may be distinguished, lying one upon the other in regular seqence, like thirteen leaves of the great book of nature belonging to the chapter on the Cretaceous series. In all of them, the fossils which they contain furnish us with precious documents explaining the zoological history of the district. Hitherto only the vertebrated animals and the Cephalopods have been carefully studied; and on these classes only can we base our remarks.

In the first place, it must be observed that no single species has extended through all the stages. According to Pictet, a complete renewal of the species took place six times; so that, even within the Cretaceous period, the species have a limit of duration; new species appear and again disappear to give place to others. Several species traverse two or even three stages; in this case they are seldom met with in the first stage, they become very numerous in the second, and then either gradually or suddenly disappear. Other species are apparently new, and, although differing in certain characters from those of the preceding stage, are yet so nearly allied to them that they are probably descended from the same original stock, and may be described as homogeneous species.

Some of the species of the Valangian approach very closely to those of the White Jura. Thus we find the *Ammonites neocomiensis*, the *A. Desori*, and the *A. marcousanus* are nearly allied with the *A. mutabilis*, *A. eudoxus*, and *A. orthoceras* of the Kimmeridge; but yet none of the species are perfectly identical, so that even the oldest Cretaceous fauna differs in all its members from the fauna of the most recent Jura. In the Valangian new and peculiar forms, which afterwards play an important part, make their first appearance. Of these Prof. Heer cites particularly the ribbed *Nautili*, which first appear in the Valangian (*Nautilus pseudo-elegans*), and occur in almost all the Cretaceous stages, in a great variety of forms.

The fauna becomes much richer in the Neocomian; and at Sainte-Croix, according to Pictet, it presents a very constant assemblage of species. The following species, which are the most abundant, almost always occur together:—*Belemnites bipartitus*, *pistilliformis*, *latus*, and *binervius*; *Nautilus neocomiensis*, *Ammonites radiatus*, *Leopoldinus*, *castellanensis*, *subfimbriatus*, *bidichotomus*, *Carteroni*, and *Asterianus*; and *Ancyloceras Duvallii*. The same group is found also at other parts of the Jura, as in the Neocomian of Mount Salève; whilst in other places a different combination of species occurs, as at Locle, where *Ammonites Asterianus*, *Arnoldi*, and *Carteroni* are found together, and *A. radiatus*, *Leopoldinus*, and *castellanensis* in an overlying bed. It is clear that the species were not uniformly distributed over the whole of the Swiss Cretaceous sea at the same time; so that each bay may present certain peculiarities in their mode of association*.

While the Neocomian of Sainte-Croix possessed 20 species of Cephalopods (including 12 Ammonites), in the following stage (the Urgonian) we find only a few traces of that class and not a single Ammonite †. This fact is the more remarkable, as the same phenomenon occurs in all parts of the Swiss Cretaceous sea. Cephalopods are wanting in the Mediterranean basin of France and in the Franco-Britannic sea; and we do not know what became of this important class of animals. It cannot be supposed that at the close of the Neocomian stage they no longer existed, and disappeared altogether from the earth during the formation of the Schratten limestone; for they reappear in the Aptian stage, which immediately follows, although their species are quite different; and at any rate those of Sainte-Croix differ greatly from the species of the Neocomian, as not one of them can be regarded as homologous.

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* The association of species depends chiefly upon local conditions. In one bay a certain assemblage of species may live; and in the next bay, which is perhaps shallower, or into which a stream flows, there may be quite a different set of species. If the faunas of these two bays were to be placed in a fossil state before us, we ought not to regard the difference in the species of one bay from the species in the other bay as a reason for referring them to different times.

† This is also the case in the Urgonian of the Landeron (Canton of Neuchâtel), which closely resembles the Neocomian, and may be regarded as the transition from it. M. P. de Loriol has described 89 species from this locality, of which 40 belong to the Mollusca, 15 to the Echinodermata, and 30 to the Sponges, which are there particularly abundant. See P. de Loriol and Gillieron, "Monographie de l'étage Urgonien inférieur du Landeron," in Nouv. Mém. de la Soc. Helv. des Sci. Nat. xxiii. 1869.

In the Urgonian stage the Mollusca, Sea-urchins, and Fishes occur in it both in the Jura and in the Alps; so that no cause inimical to animal life can have driven the Cephalopods from the Urgonian seas*.

In the Aptian stage, Cephalopods are by no means abundant; but they reappear here under varied forms of Ammonites, Nautili, and Belemnites, which for the most part stop at this stage, although some of them extend up into the Gault. The Gault is rich in fossils, which, at Sainte-Croix, are distributed upon three distinct subordinate stages—the Lower, Middle, and Upper Gault. The Lower and Middle Gault have more species in common than the Middle and Upper Gault possess. At Sainte-Croix the Upper Gault is characterized by a series of peculiar forms. Of 40 species of Cephalopods the majority occur in this division; here the genera *Anisoceras* and *Scaphites* first appear at Sainte-Croix; but *Hamites, Ptychoceras,* and *Baculites,* which appear in the Middle Gault, change some of their species in the Upper Gault; of the 18 Ammonites, 2 species (*A. latidorsatus* and *A. Raulinianus*) occur also in the Middle Gault, whilst most of the Belemnites ond Nautili are distributed through all three divisions. We see, therefore, that during the Gault period at Sainte-Croix many species maintained their position, but others died out or emigrated, whilst others, again, took their place, and thus a new mixture of forms occurred, and no doubt went on without interruption.

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* It is remarkable that the Cephalopoda are deficient at the time when the chloritic grains disappear from the marine deposits. Consequently at the time of the Neocomian and the Gault, the sea-water must have differed somewhat in constitution from that of the time of the formation of the Schratten limestone. In the Seewen limestone also, which is destitute of green grains, Ammonites are rare. Can this remarkable phenomenon be explained by the slight difference in the constitution of the sea-water?

The Cenomanian closes the Cretaceous formation at Sainte-Croix. Its species are quite different from those even of the upper division of the Gault. The number of species in the Cenomanian is much smaller; and we see in this stage the commencement of the gradual extinction of the Ammonites and Belemnites, which entirely disappear in the uppermost Cretaceous stages.

At Sainte-Croix, and throughout the Jura, the Cenomanian is the highest stage of the Cretaceous series. In the north of France, however, three more stages lie over it—namely, the *Turonian* (Hippurite limestone), the *Senonian* (or White Chalk), and the *Danian*. Whether the Seewen limestone of the Alps represents only one or more of these stages, has not yet been ascertained with certainty.

This glance at the evolution of the fauna as mirrored forth in the Cretaceous formations of Sainte-Croix, shows not only that a peculiar mixture of species occurs in each stage, but also that the majority of the forms in each stage belong to it alone; each stage includes its own special fauna, which may be united by certain species with the faunas of the neighbouring stages, but does not melt into them insensibly. If we compare the sequence of the species with those of other parts of the Swiss Cretaceous sea, a similar development will be found to occur; but in many places there is a different association of the species and a less distinct separation of the different stages. Thus, at the Perte-du-Rhône, the Aptian has more species in common with the Gault than at Sainte-Croix.

The fauna of the Upper Gault at Sainte-Croix differs in all its species from the fauna of the Cenomanian; but at the Col-de-Cheville*, at the foot of the Diablerets, in the Canton of Vaud, there is a remarkable intermixture of the species of these two stages. On the Altenmann Alp, at Alvier, Prof. A. Escher de la Linth found in the Neocomian a sea-urchin scarcely distinguishable from the *Galerites castanea* of the Gault; and *Collyrites ovulum*, Des., from this locality is remarkably near *C. Moussoni* from the Gault. All this shows that the various stages of the Cretaceous frequently overlap each other as regards their organic contents, and that this circumstance is more clearly seen from a wider area of investigation.

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* Prof. Renevier distinguishes three Cretaceous stages in the environs of Cheville. He places the oldest in the Lower Gault, the middle one in the Upper Gault (Lower Cenomanian, Vraconian), and the uppermost in the Rhotomagian. See "Notices géol. et paléont. sur les Alpes Vaudoises," in Bull. de la Soc. Vaud. des Sci. Nat. tome ix. pp. 105 & 389.

The species must have had definite foci from which they were distributed; and their diffusion will have been favoured or obstructed by the occurrence of marine currents in definite directions, and of localities favourably situated for habitation and increase, the places of abode being further modified by the circumstance of their having been previously unoccupied or more or less densely populated. In proportion as a species was more tenacious of life, better adapted to maintain its existence under different external conditions, and more capable of increase, and the longer the period of its existence; or, in other words, the older it was, the larger will also, in general, be its area of distribution. Now, as it is very probable that all species did not issue from the same point, and as their relation to external conditions, their age, and their faculty of reproduction are very different, the combination of species at the same time and within the same sea-basin must also show a certain variety in its different parts.

If we transfer ourselves in imagination to the Necomian period to make a voyage along the shores of the Swiss Cretaceous sea, we shall find in most places great masses of the remains of animals thrown by the ocean on the strand. Many species will meet us everywhere. We shall find in all parts curious Belemnites (*B. pistilliformis* and *latus*), splendid *Nautili* (*N. pseudoelegans* and *Neocomiensis*, fig. 118), Ammonites (such as *A. radiatus*, *subfimbriatus*, *Carteroni*, *Asterianus*, and *neocomiensis*), and large folded oysters (*Ostrea macroptera*, fig. 132, and *O. Couloni*). With this set of generally distributed species, however, we shall find at each spot some peculiar forms. When the limestones of the Sentis and the Kurfürsten were deposited we shall observe several peculiar Ammonites (such as *A. pulchellus*, *Calypso*, and *Matheroni*); in the bay of the Moléson island a crowd of *Ancyloceras* and *Hamulina* with elegantly coiled shells and numerous other Ammonitidæ, some like straight rods (*Baculites Renevieri* and *Meyrati*) and some curiously bent (*Ptychoceras Meyrati, Morloti,* &c.). Passing over to the western coast, we shall see almost everywhere the same species of Cephalopods, but with them are associated sharks and great sea-lizards.

If we make the same journey in Urgonian times, perhaps a hundred thousand years later, we shall be surprised to find that the Cephalopods, which, with their beautiful pearly colours and the varied forms of their chambered shells, constituted a principal ornament of the marine fauna during the Neocomian, have almost entirely disappeared. But here and there along the coast we find coral reefs, and generally distributed the Ram's-horn shells (*Requinia Lonsdalii,* D'Orb., and *ammonia,* D'Orb., fig. 133), *Orbitolinæ,* a very large wing-shell (*Pterocera pelagi,* Br.), several *Nerineæ,* and a sea-urchin (*Toxaster oblongus*), intermixed in each locality, as in Neocomian times, with a number of peculiar species.

Let us next visit the same shores at the time of the Gault, a hundred thousand years later, and we shall see the coast covered with numerous sea-urchins and bivalve and univalve shells, associated, as in Neocomian times, with Cephalopods which have changed their livery, appearing not only as new species, but partly also of different genera (such as *Turrilites* and *Helicoceras*), although in the association of forms the same general conditions prevail. The number of species of animals is greater than in the earlier Cretaceous stages, and the species are more widely distributed.

A fresh modification of animal life is presented in the formation of the Seewen limestone. In the region of the Swiss eastern Alps there is no longer an abundance of large marine animals, of bivalves, univalves, &c.; and although we still see some Ammonites (such as *A. peramplus* and *dispar*), some Turrilites, and a few *Inocerami* (*I. Cuvieri* and *Crispii*) and sea-urchins (*Ananchytes ovata,* fig. 117, and *Microgaster cor-anguinum*), the number of species has become much smaller. But if we examine the mud thrown up on the shore, we find in it innumerable microscopic animals, which tell us that even at this time there was an abundance of life in the depths of the sea. In the western Alps (at the Col-de-Cheville) and at Sainte-Croix numerous Mollusca also occur; and here the fauna has become much more uniform. Subsequently the sea retreated from the Jurassic coast, but continued for a long time to occupy the Alpine zone.

During all the stages of the Cretaceous period we notice that the marine fauna of Switzerland preserved the special character of each epoch. If, at intervals of ten thousand years, we could a hundred times have visited the shores of the Swiss Cretaceous sea, we might perhaps have been able to trace the gradual transformation of these faunas, and to demonstrate how they mutually acted on each other, so as to produce the general picture of animal life, the remains of which we find in a fossil state.

In order that we may obtain a clear idea of the plants and animals of the Swiss Cretaceous period we must now give a careful consideration to the principal forms of the flora and fauna belonging to that epoch.

Of the flora of the Cretaceous sea we certainly know very little. About a dozen species from the Neocomian have been observed, the most frequent being two species of Algæ, which form black or light-coloured bands upon the stone. One species (*Chondrites serpentinus*, Heer, fig. 99) forms narrow, curved and but slightly branched bands, the branches having parallel sides and rounded sides. Prof. Heer has seen it from Châtillon-de-Taverne (Canton of Vaud), from the Justithal, and from the Ripрächter-Mähren (in the Bernese Oberland). The second species, which is nearly allied to the preceding (*Chondrites Meyrati*, F. O., sp.), is larger and has more delicate but broader ramifications, the extreme branches being short and widening towards the end. This species is common in the Neocomian of the Justithal, of Merlingen, and of Meruet below Argentine (Canton of Vaud). Prof. Heer has received it from Northern Italy (from St. Florian above Sennavalle); so that it was widely distributed at that epoch. The Nulliporites are represented by a species (*N. granulosus,* Heer, fig. 103) which has very delicate

Fig. 99. Fig. 100. Fig. 102. Fig. 100.

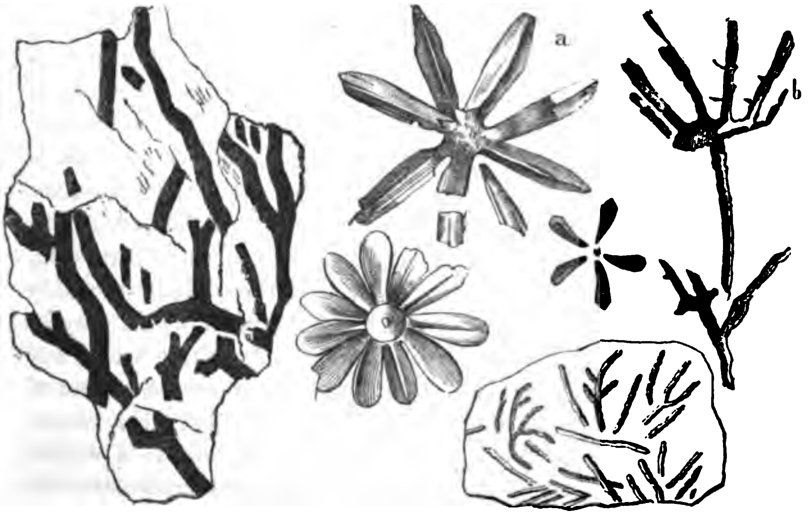


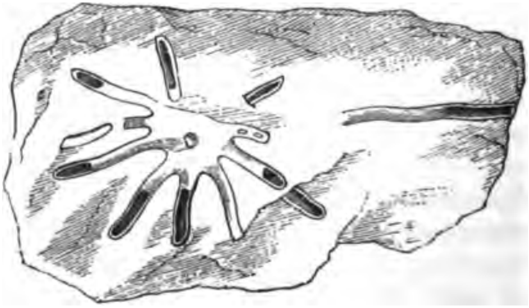
Fig. 101. Fig. 103.

Fig. 99. *Chondrites serpentinus,* Heer, from Châtillon-de-Taverne.
Fig. 100 *a.* *Gyrophyllites Oosteri,* Heer, from St.-Denis.
Fig. 100 *b.* *Discophorites angustifolius,* from St.-Denis.
Fig. 101. *Gyrophyllites obtusifolius,* Heer, from St.-Denis.
Fig. 102. *Gyrophyllites pentamerus,* Heer, from St.-Denis.
Fig. 103. *Nulliporites granulosus,* Heer, from Marwies on the Sentis.

cylindrical and apparently granulated branches. Of this, numerous specimens have been found on laminæ of the rock of Marwies on the Sentis. A second species (*N. fusiformis,* F. O., sp.) from Ringgenberg, near the Lake of Thun, is larger and has stout spindle-shaped branches. A plant described as *Cylindrites arteriæformis,* Göpp., forms a network of ridges as thick as one's little finger upon the slabs of stone which are quarried near Leyssingen, in the neighbourhood of the Lake of Thun; it is probably nearly allied to the plants which produced similar branched ridges in the Lias and White Jura (see pp. 95 and 143).

The preceding plants all belong to the Algæ; but there is another vegetable form, several species of which have lately been discovered in the Neocomian, the position of which in the system is still doubtful. The leaves are placed in whorls of from five to eleven, reminding us of the *Annulariæ* of the Carboniferous epoch; but the stem is thicker, all the leaves are of the same size, not united at the base, of more delicate structure, and traversed along the middle by a broad, flat vein, which is frequently obsolete—all characters which remove them from the *Annulariæ*. Moreover, in the localities where they occur, as, for instance, at Châtel Saint-Denis, in the Canton of Fribourg, only marine animals are found; so that these plants probably lived in the sea and belonged to the Algæ, in which may be remarked the same verticillate arrangement of their leaves and branches. Prof. Heer is acquainted with three species, one of which (*Gyrophyllites obtusifolius*, Heer, fig. 101) has eleven leaves, obtusely rounded at the end in each whorl; a second species (*G. Oosteri*, Heer, fig. 100 *a*) has eight lanceolate and pointed leaves in each whorl; while in the third (*G. pentamerus*, Heer, fig. 102) the whorl has ouly five leaves, which are very narrow at the base and obtusely rounded at the end. *Discophorites angustifolius*, Heer (fig. 100 *b* and 103 B) also probably belongs to this group; it has narrow linear leaves

Fig. 103 B.



Discophorites angustifolius, Heer.

inserted at the base of a flattened disk, which gives this plant a very peculiar character*.

The Diatomaceæ were numerous during the Cretaceous period, but they have not yet been discovered in the Swiss rocks of that age. They are microscopic unicellular plants, covered by a strong siliceous shield, and usually live collected together in a large gelatinous mass of a brown or golden yellow colour, which, after death, becomes green. The beauty and variety of these minute plants shows us how wonderfully nature can adorn and diversify even the smallest and most insignificant structures; and their great power of reproduction by simple division produces an astonishing multiplication of individuals†.

As the siliceous shields of these minute plants are indestructible either by heat or by decay, they remain unaltered for hundreds of thousands of years; and thus the siliceous coats of these vegetable pygmies have come down to us from the earliest ages of the earth. In the Cretaceous epoch they were very abundant; and Ehrenberg has shown that the Firestones of that formation consist in great part of Diatomaceæ ‡.

If these minute siliceous plants have had an essential part in the building up of the crust of the earth, this is still more strikingly the case with the small animals belonging to the class Rhizopoda. Some of these (the Radiolaria or Polycystina) have a siliceous coat or framework, and others (the Polythalamia or Foraminifera) a calcareous shell. The former live in immense numbers near the surface of the water, where they form gelatinous masses, which, under the microscope, exhibit an astonishing variety of forms and a marvellous elegance of siliceous structure. Many species have been observed in a fossil state;

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* Prof. Heer has recently received many well-preserved specimens of *Discophorites angustifolius* from St.-Denis, where they occur in a bed below the Fish-bed.

† Ehrenberg has calculated that, under favourable circumstances, a single Diatom might in four days produce 140 billions of individuals.

‡ According to Ehrenberg a cubic inch of the polishing slate of Bilin, in Bohemia (Tertiary), contains about 41,000,000,000 and a cubic foot about 70 billions of siliceous shields.

and in some places they have assisted in the formation of rocks.

The Polythalamia are distinguished from the Diatomaceæ and the Radiolaria by their calcareous shells; and they are also characterized by the structure of these shells, which frequently resemble Lilliputian Ammonites, the spirally coiled shell being divided into chambers. This shell is perforated like a sieve by numerous excessively small pores (whence the name Foraminifera); and the animal itself is of very simple structure. It has a soft slimy body, which sends out gelatinous threads through the pores of the shell. As the animals of this class move by means of such finger-like or root-like processes pushed out from their bodies, they have received the name of Rhizopoda.

The Polythalamia do not increase by division, but by eggs; and as they occur in enormous quantities they must possess a power of reproduction as great as that of the Diatomaceæ; they have also, like the Diatomaceæ, assisted in the formation of sea-mud and the production of rocks.

Every fragment of limestone in the pyramids of Giseh, and the catacombs of Thebes in Egypt, is composed of milliards of elegant little shells: the limestone (*calcaire grossier*) of which Paris is built is chiefly the product of similar excessively small creatures (*Miliola*); the white chalk rocks which first meet our view on the English coast consist of countless billions of the shells of Polythalamia. The Cretaceous rocks of Switzerland are also in part constructed by these wonderful little creatures, as has been shown by Professor Kaufmann of Lucerne, who has had the kindness to furnish Prof. Heer with the results of his labours, which are here reproduced. As these little animals have contributed essentially to the construction of the Swiss Cretaceous Alps, they deserve to be noticed in some detail. M. Kaufmann has found them in the Schratten limestone, the Gault, and the Seewen limestone: they are best preserved in the last; and we will therefore first examine the forms which generally occur in that portion of the Upper Cretaceous series.

A. POLYTHALAMIA OF THE SEEWEN LIMESTONE.

Neither with the naked eye nor with the lens can any thing recognizable be detected in the compact homogeneous Seewen limestone; and even the microscopic examination of finely cut surfaces rubbed with oil reveals merely a few delicate dark lines, which may be recognized as the chamber-walls of Polythalamia; but they stand out very little from the grey ground, and may easily be overlooked. But, by a peculiar mode of preparation, these lines may be made to appear much more numerous and distinct. A cut and polished fragment of the stone is treated by the blowpipe until it is red hot; it is then left to cool. If the heat is continued longer, the stone is decomposed, and all organic traces disappear. The polished surface is then oiled and examined under the microscope by direct sunlight, when

Fig. 104.

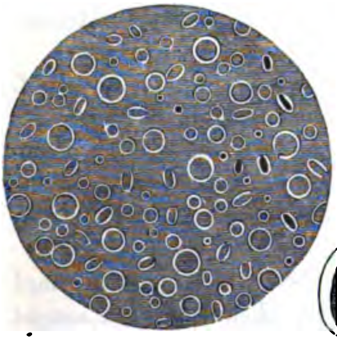


Fig. 106.

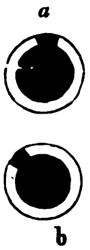
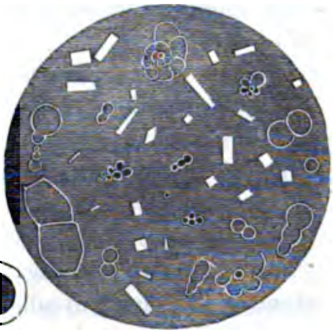


Fig. 105.



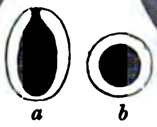


Fig. 107.

Seewen limestone.

Figs. 104 and 105. Polished surfaces of the stone from the great quarry near Seewen, magnified 50 diam.

Fig. 106. *Lagena sphærica*, Kaufm., magn. 200 diam.

Fig. 107. *Lagena ovalis*, Kaufm. *a*, longitudinal, and *b*, transverse section, magn. 200 diam.

the fine walls of the chambers appear white and the surrounding ground grey or blackish, as represented in figs. 104 and 105.

Fig. 104 shows what usually occurs—a number of ring-shaped and elliptical bodies, generally with a few scattered larger forms like those in fig. 105. The latter are visible with the simple lens even on the unpolished and uncalcined stone, but only under strong sunlight. The appearance shown in fig. 104 was observed at Seewen, near Gersau, at the Vitznauerstock, at Bürgen, the Rotzberg, and the Mutterschwandenberg, and in a specimen in the Museum at Zurich from the Meglisalp at the Sentis. It may also be observed in the reddish variety of the Seewen limestone which occurs on the southern declivity of the Urmiberg, near Brunnen. The view shown in fig. 105 is less frequent; it has been observed in specimens from Seewen and the Rotzberg. Many other large forms occur in polished sections, besides those represented in this figure. The meaning of the white rods is not yet made out. When isolated, they appear to be solid prismatic bodies composed of carbonate of lime.

Among all the fragments of Seewen limestone that Prof. Heer has examined he has not seen one in which the characters just described did not occur in one form or the other. From this an approximate idea may be gained of the infinite number of microscopic organisms accumulated in the Seewen limestone.

For the closer investigation of the little shells, polished hard stone is of course ill-adapted; but the shells must be sought in the softer marly parts of the rock, and examined microscopically when isolated. For this purpose the mass is mixed with water, and the finer part of the residue separated and dried. The detection of the larger forms is attended with considerable difficulties; but the smaller ones, not exceeding $\frac{1}{5}$ millimetre (or ·008 of an inch) in dimensions, may be rendered visible by adding balsam to the fine residue. Canada balsam, which was employed by Ehrenberg, renders the object very clear; but as it becomes hard, it has the inconvenience of preventing the specimens from being turned about. Balsam of Peru is to be preferred, as it remains fluid. By this means many forms from the Seewen limestone have been examined; and among them the most widely distributed are the following six species of Polythalamia:—

1. *Lagena sphærica*, Kaufm. (*Miliola arcella*, Ehr.?; *M. sphærula*, Ehr.?), fig. 106. The shell is transparent, smooth, calcareous, and spherical, but sometimes departing more or less from a spherical form, as if compressed. The wall varies in thickness (from 0·003 to 0·01 millimetre). The interior is usually dark, often filled with a granular or crystalline mass. The orifice is round, not rayed, and generally perceptible only when the object is so turned that the mouth is placed at the margin. Diameter from 0·035 to 0·1 millimetre. This is the form which produces the white rings on the polished stone (fig. 104); and it is consequently the commonest fossil of the Seewen limestone, a cubic inch containing millions of the shells. The isolated individuals (fig. 106) are from Seewen and Rotzloch. This species occurs in innumerable quantities in the White Chalk of Rügen; it is there generally filled with air. It is not unfrequent in the Gault (at Rotzloch, Bürgen, and Urmiberg), especially in the upper beds.

2. *Lagena ovalis*, Kaufm., fig. 107 (*Miliola ovum**, Ehr., in part?). The shell is oval, smooth, transparent, calcareous, without pores and circular in transverse section, but sometimes more or less compressed. The walls are generally thick, but commonly thin at the bottom; internally they are frequently irregular, as if set with crystals. The interior is often filled with an opaque mass. The mouth is round, without rays. The length of the shell is from 0·05 to 0·075 millim. In the section (fig. 104) it forms the oval figures. It is constantly associated in the Seewen limestone with *Lagena sphærica*, and yields but little to it in abundance, so that these two species have contributed far more than any others to the formation of the Seewen limestone. The isolated specimens of the *Lagena ovalis* (fig. 107) are from Seewen. Prof. Heer has found the same species in innumerable multitudes in the Chalk of Rügen (Baltic), usually filled with air. The resemblance of

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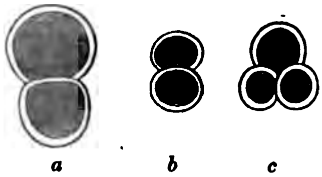
* It agrees pretty closely with Ehrenberg's *Miliola ovum* from the island of Moën, in his 'Mikrogeologie,' pl. 29. fig. 45, but not with the figures on plate 23 (from the Nummulitic formation) and plate 31, which are also referred by Ehrenberg to *Miliola ovum*.

this chalk to the Seewen limestone, as regards the abundance of these two animacules, could not be more complete. Here and there *Lagena ovalis* also occurs in the Gault (as at Rotzloch and Mutterschwandberg).

3. *Oligostegina lævigata*, Kaufm. (fig. 108). In this new genus the shell consists of two or three chambers. The wall of the second chamber has a notch, by means of which it embraces a portion of the first; and so far as this is the case, the wall of the latter is thin. The third chamber touches the first and second; and all three chambers are in the same plane. The aperture is unknown.

Fig. 108.



Oligostegina lævigata, Kaufm. Magnified 200 diameters.

Prof. Rupert Jones takes this species for the early chambers of the *Planorbulina globulosa*, Ehr., or of the *Textilaria globulosa*, Ehr.

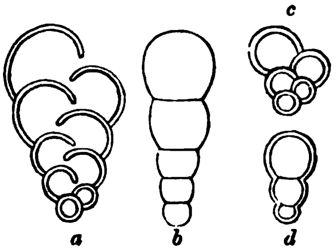
It might be supposed that these forms are only young states of larger many-chambered species, such as the *Nonioninæ*. But this is contradicted by the circumstance that the two-chambered form is very abundant, whilst those with three chambers are rather rare.

The shell of the only known species is transparent, calcareous, and smooth. The chambers are globular, the first spherical, and generally rather smaller than the second. Diameter from 0·05 to 0·12 millimetre.

The two-chambered form is pretty widely diffused in the Seewen limestone (Seewen, Gersau, Bürgen, Rotzloch), and in the white chalk of Rügen (Baltic). It is abundant also in the middle and upper beds of the Gault (Mutterschwand, Rotzloch, Bürgen, Vitznauerstock, Urmiberg); in the Urmiberg it occurs in great quantities. The three-chambered form has been found here and there in the Gault, but more in the upper than in the middle beds.

4. *Textilaria globulosa*, Ehr., fig. 109. The shell is transparent, calcareous, smooth, three-sided, a little compressed, with the margins rounded, obtusely limited below and obliquely above. There are from three to five chambers on each side; they are globular, and separated by rather deep sutures. The aperture is rendered visible, especially on the older chambers, by the walls not closing perfectly at the inner margin. Diameter from 0·04 to 0·15 millimetre.

Fig. 109.



Textilaria globulosa, Ehr. Magnified 200 diameters.

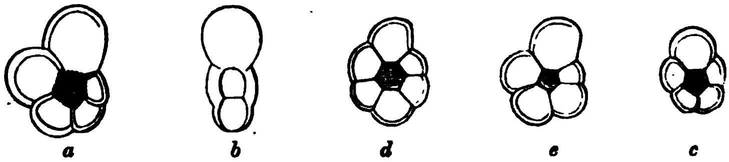
It varies much in the number of chambers, which are sometimes a little angularly rounded or widened. The extreme forms, however, are united by transitions; so that, as species, they cannot be separated.

This species is common in the Seewen limestone (Seewen, Gersau, Bürgen, Rotzloch), and equally plentiful in the White Chalk of Rügen and England (Lewes in Sussex, Charlton, Kent), and in the Pläner limestone of Töplitz. Ehrenberg mentions it from the White Chalk of Egypt, the Antilibanus, Meudon near Paris, Gravesend in England, the island of Moën, Wolsk on the Volga, and from the regions of the Missouri and Mississippi.

5. *Nonionina Escheri*, Kaufm., fig. 110. The shell is transparent, calcareous, smooth, rather strongly compressed, somewhat ovate when viewed from the broad side, and more or less lobate. Five or six convex chambers surround the first or central chamber, which appears like a pentagon or hexagon, of a

dark colour and of variable size. The last chamber (and sometimes also the last but one) is often much inflated, by which strong sutures are produced between the chambers. The aperture is not visible. The construction is distinctly equilateral. Diameter from 0·055 to 0·12 millimetre.

Fig. 110.

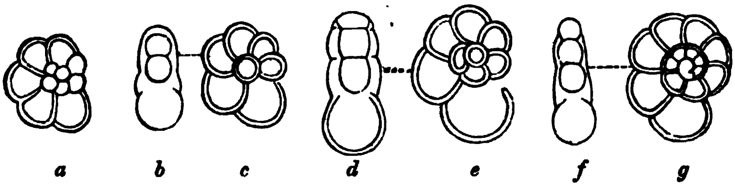


Nonionina Escheri, Kaufm. Magnified 200 diameters.
(*Globigerina cretacea*, D'Orb.)

This species, which was dedicated to Professor Escher de la Linth, is not uncommon in the Seewen limestone (Seewen, Gersau) and in the White Chalk of England. It is frequent in the middle and upper beds of the Gault of the Rotzloch and Urmiberg.

6. *Nonionina globulosa*, Ehr. sp., fig. 111. The shell is rounded or ovate, transparent, calcareous, smooth, more or less compressed. The chambers are globular, and the sutures deep. The septa are straight or slightly curved. One or two spiral turns may be observed. The aperture is situated at the inner margin of the chambers, but is not always visible. Diameter from 0·55 to 0·1 millimetre.

Fig. 111.



Nonionina globulosa, Ehr., sp. Magnified 200 diameters.
(*Rotalia*, *Phanerostomum*, and *Planulina*, Ehr., sp.)

Much as many of the forms of this microscopic shell differ from one another, they must not be separated as species, as they are connected by intermediate forms.

To show the near relationship of the forms here brought together, cover the last two chambers in fig. 111, *c*. There will remain an outline which does not differ essentially from *e* and *g*; so that *c* appears to be only an older individual. In the same way the other forms may be derived from each other.

This species is abundant in the Seewen limestone of Seewen, Gersau, Bürgen, and Rotzloch, and also in the White Chalk of Rügen and England, in the Turonian of Maidstone in Kent, and in the Pläner limestone of Töplitz. It is not rare in the Gault (Urmiberg, Mutterschwand).

B. POLYTHALAMIA OF THE GAULT.

On the Rotzberg, Bürgen, and Vitznauerstock the Gault consists:—

a, *in the lower beds,* of a coarsely spathose grey limestone, resembling an echinodermic breccia with a few green granules. If this stone be cut and heated, and magnified under a power of 50 diameters, it appears to have a coarse coral-like network. It contains no Polythalamia.

b, *in the middle beds,* of a dark more or less nodular or indurated shale, full of green granules (which are often microscopic), and generally with many fossils (*Inoceramus concentricus*).

c, *in the upper beds,* of a grey or blackish, hard, siliceous limestone with numerous green grains, which is either compact or (especially towards the neighbouring Seewen limestone) traversed by thin layers of a dark green substance deposited in an undulated form, and weathering less at the surface than the limestone; between the layers are inserted lighter-coloured ellipsoidal nodules, such as are usually seen in the Seewen limestone.

Almost throughout the beds *b* and *c*, Polythalamia occur—in the uppermost bed in great quantities. They are, however, visible on the cut and polished stone only after it has been heated to redness, when the green grains of glauconite become black, and the particles of iron pyrites become red by oxidation.

Fig. 112.

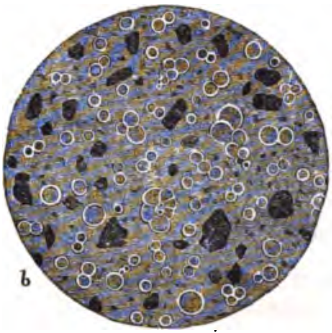
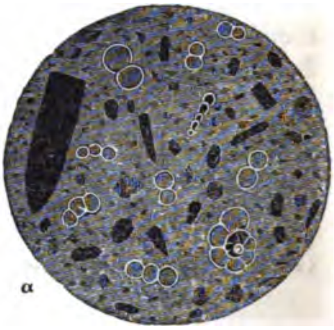


Fig. 113.



Gault, cut and polished surfaces. Magnified 50 diameters.

Fig. 112. From an ellipsoidal nodule of the uppermost beds, from the Bürgenstock.

Fig. 113. From the middle shaly beds of the upper peak of the Vitznauerstock.

a. Glauconitic grains. *b.* Pyrites.

The similarity of the microscopic forms of the Gault and the Seewen limestone here strikes us at once. In the Seewen limestone the aggregation of individuals is, on the whole, greater; for in the Gault we sometimes find little or nothing, especially in places where the green grains and the particles of pyrites are abundant. Besides, whilst the *Lagenæ* predominate in the Seewen limestone, in the Gault the *Oligostegina* are in the greatest numbers.

Many of the Swiss Gault rocks are so like the Nummulitic Greensand and the dark siliceous limestones of the Neocomian (especially the Altmann beds, which are dotted with green points) that, when fossils are absent, they are undistinguishable. By the method of examination already described, it is possible to distinguish the Gault rocks, since, if we may judge from repeated experiments, no similar organic forms occur in the Nummulitic Greensand or Neocomian rocks.

The isolation of the shells was effected by the same process as in the case of the Seewen limestone. The following species were detected: *Lagena sphærica, L. ovalis, Oligostegina lævigata**, *Nonionina Escheri, N. globulosa,* and some others, which, however, have not been sufficiently investigated, and some of them are too rarely met with to be mentioned here.

The occurrence of identical species in the Seewen limestone and the Gault is the less remarkable since the extended researches of Reuss have shown that many species of Polythalamia of the White Chalk descend into the lower stages (the Turonian and Cenomanian), and some even into the Gault. In Switzerland, as elsewhere, there is no decided limitation of these Polythalamia downwards, except between the Gault and the Urgonian. The near relationship of the Gault and Seewen limestone is confirmed by their common distribution in Switzerland, where it is well known that both stages either occur together or both are wanting.

C. POLYTHALAMIA OF THE URGONIAN.

The sketches in fig. 114 only represent sections which are produced accidentally by cutting the stone; but even in this imperfect form the Polythalamia of the Urgonian are so easily recognizable, and at the same time so generally distributed, that they are admirable characteristic fossils. A fragment of rock may be broken off, and the fractured surface moistened and examined in good daylight with a lens, and in most cases what is looked for will soon be discovered. These little bodies are usually accumulated in particular abundance in the middle and upper beds of the Urgonian stage (including the beds with *Orbitolina lenticularis*), so that they appear by dozens in the field of the lens, and form a considerable part of the mass of the stone. But they appear still more numerously and distinctly upon the polished surface of the stone when it is moistened with oil, as for example in the black döllite, which is frequently cut and polished for pedestals. The shells have thick white walls to their chambers, the arrangement of which particularly resembles that of the group Agathidostegia, in which the chambers are coiled nearly like the threads of an oval ball of yarn. In a transverse section the chambers resemble rounded or semilunar holes (fig. 114, *a–g*); in a longitudinal section they appear as slightly curved or sickle-shaped canals (fig. 114, *h–l*). It is rare, however, to find a longitudinal section which does not cut

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* According to Prof. Rupert Jones, the *Lagena sphærica, L. ovalis,* and *Oligostegina lævigata,* Kaufm., are single and attached chambers of *Planorbulina Textilaria,* and *Globigerina.*

Fig. 114.

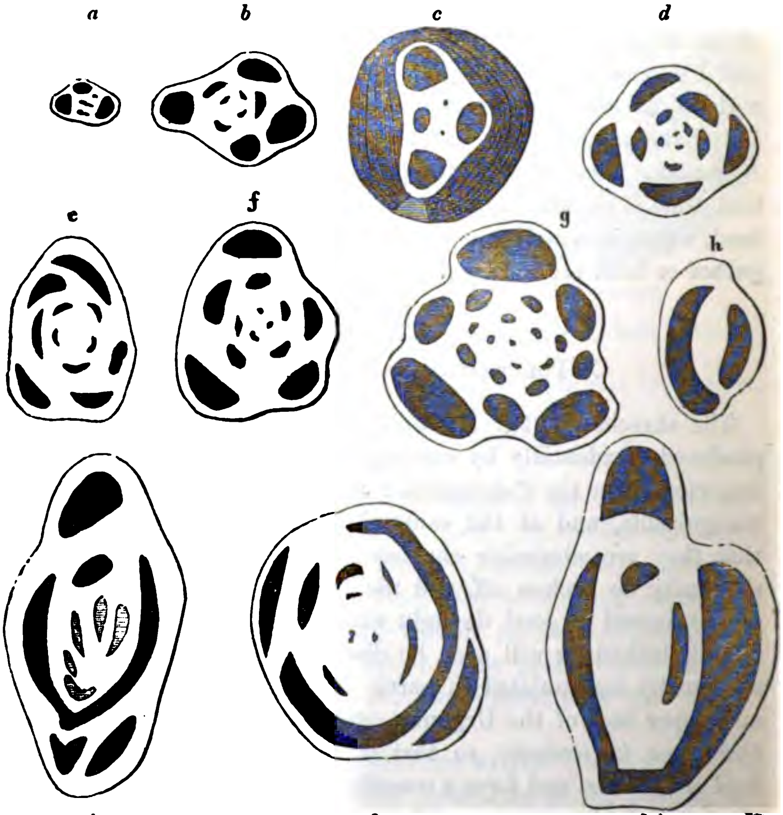


Fig. 114. Sections of Polythalamia (*Miliola*) of the Urgonian. Magnified 50 diameters.

a, *b*, *d*, and *h–l*. From the Bürgenstock.

c. Oolitic grain from the Hohfluh (Canton of Schwyz).

e, *f*, *g*. From the Döllite of the Lopperberg near Alpnacht.

one or more of the chambers obliquely. The Urgonian is often oolitic, in which case a Polythalamian shell is sometimes concealed in the interior of the grains, as, for example, in the thick beds of Urgonian near Föhnenberg, on the southern declivity of the Hohfluh (fig. 114, *c*).

Repeated observations seem to prove that these Polythalamia are entirely confined to the Urgonian stage. They have not been obtained elsewhere in the isolated state.

The researches of Professor Kaufmann have been chiefly directed to the Cretaceous rocks of the limestone mountains surrounding the Lake of the Four Cantons; and it is also probable that the mountains of the Cantons of Glaris and Appenzell, which belong to this formation, have been for the most part built up by similar animalcules. Thus the Seewen limestone of Obstalden (in the Canton of Glaris) contains an immense quantity of Polythalamia—the *Lagenæ, Textilariæ,* and *Nonioninæ* lying together in dense masses. The upper Cretaceous limestone of the Mountains of Ammon and the Sentis swarm with the shells of these little creatures, among which Pastor Zwingli has recognized *Textilaria globulosa* and *Nonionina globulosa.*

The *Orbitolinæ* constitute a peculiar form of animals of the Cretaceous period: their position in the system is still doubtful; but they seem to be most nearly allied to the Polythalamia. They form little saucers (fig. 115), slightly convex on one side and slightly concave on the other. They exhibit very delicate

Fig. 115.

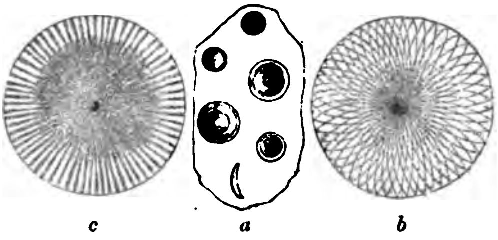


Fig. 115. *Orbitolina lenticularis.*
a, natural size, from the Val Travers. *b, c*, much enlarged: *b*, the convex side; *c*, the concave side.

concentric circles placed very close together. When slightly cut away, radiating striæ appear on the concave side, especially towards the margin (fig. 115, *c*)—but on the other side numerous pores so arranged as to form both concentric circles and curved spokes which, running towards the margin, mutually cut each other (fig. 115, *b*). In a brownish-yellow marl of the Lower Aptian, at the Perte-du-Rhône, *Orbitolina lenticularis*, Blum., sp. (fig. 115, *a*), forms a bed about 1½ foot thick; this species also occurs at La Presta (in the Val Travers) and at Sainte-Croix, as well as in the Vaudese Alps; we also meet with it in great quantities in the Urgonian of the Cantons of Appenzell and Glaris. It is therefore an easily recognizable form very characteristic of this epoch.

The *Corals*, which were so important in the Jurassic sea, have by no means disappeared, and some of them belong to the same genera (*Astræa, Lithodendron*, &c.); but at present we know of no extensive coral reefs belonging to the Cretaceous sea. It is true that on the Käserenalp (in the Canton of Schwyz), and on the Meglisalp, Oehrli, and Siegelalp (in the Canton of Appenzell), we find larger or smaller associations of such corals; but they nowhere form large rock-masses, and in the Jurassic Cretaceous rocks they do not occur at all, although it is exactly in that shallow sea that we should expect to find them. On the other hand, *Sponges* are frequent there; Loriol has described thirty-one species, belonging to sixteen genera, from the Neocomian of the Salève.

Of the *Echinodermata*, we find *Crinoids*, as in the more ancient seas, but much less frequent; *Pentacrinites cretaceus*, Leym., occurs in the Canton of Appenzell.

The *Sea-urchins* are much more important members of the Cretaceous marine fauna: they consist of numerous forms in the Swiss Cretaceous rocks; and peculiar species characterise certain stages. The turban-urchins (*Cidaridæ*), with which we are already acquainted (p. 130), do not appear so abundantly as in the Jurassic sea; but they are still developed in many forms, and show an equally remarkable variety in the formation of their spines, which are smooth, warty or ribbed, clavate, spindle-shaped or pear-shaped. These turban-urchins only form a continuation of the Jurassic types; whilst in the Heart-urchins (*Spatangidæ*) we have a new series of forms, which is peculiarly characteristic of the marine fauna of this epoch. In these sea-urchins the test is thin, and has at one place a deep furrow-like impression, which gives it a heart-like form. Of the five ambulacral areas one lies in this furrow, but it is generally rudimentary. The unarmed mouth is not placed in the centre. The most important genus in the Swiss fauna is *Toxaster*, specially distinguished by its curved ambulacral areas; all its species are Cretaceous. *Toxaster Brunneri*, Mer. (fig. 116, *a, b*), is abundant in the uppermost Neocomian of the Alps; in the rocky walls of the Drusberg (in the Canton of Schwyz) whole armies of this marine animal are buried. It also occurs

Fig. 117.

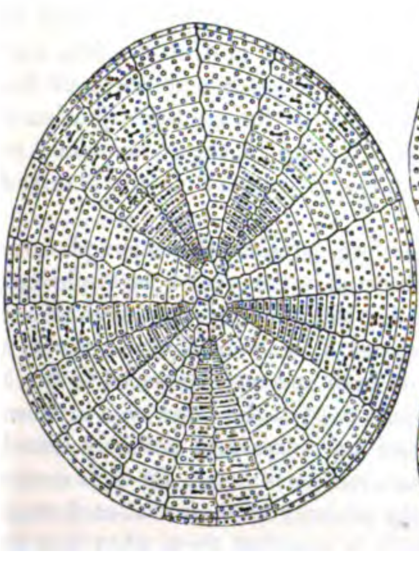


Fig. 116.

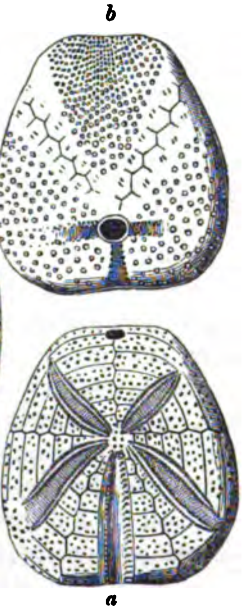


Fig. 116. *Toxaster Brunneri*, Mer.
Fig. 117. *Ananchytes ovatus*, Lam.

in great numbers on the Kurfürsten (between Brisi and Frumsel) and on the Sentis. *Toxaster sentisianus*, Des., has a similar distribution; it was collected by A. Escher de la Linth in a lower division of the Neocomian, not only on the Sentis, but also high up on the Firenbänder of the Glärnisch; and it occurs in abundance in the Valangian at the foot of Mount Pilatus. The nearly allied *Toxaster complanatus*, Ag., occurs chiefly in the Neocomian of the Jurassic zone, but is by no means absent from the Alps; it was found by Professor Desor in the Canton of Unterwalden, at the foot of Mount Pilatus. It also lived in the Mediterranean basin and in the Franco-Britannic sea, and was known in the north of France, England, and Germany. In the Aptian, *Toxaster oblongus*, Del., sp., has a similar wide distribution. *Toxaster Couloni*, Ag., and *T. granosus*, D'Orb., had a narrower range, and lived only on the Jurassic coasts of the Swiss sea. Of the nearly allied genus *Micraster*, one species (*M. polygonus*, Ag.) is also confined to the Swiss Jurassic shores, whilst another (*M. cor anguinum*, Lam., sp.) is found in the Seewen limestone of the Sentis and of Unterwalden, and also in the White Chalk of both the south and north of Europe. *Holaster subglobosus*, Leske, sp., has the same distribution in the Upper Cretaceous, and *H. l'Hardyi* in the Neocomian; on the other hand, *H. lævis*, Del. sp., is confined to the Gault of the Jurassic zone.

The Sea-urchins, therefore, present the same phenomenon which we have already observed in the case of the Cephalopods—namely, that many species were limited to the southern and others to the northern shores of the Swiss Cretaceous sea, whilst others, again, occurred on both and may be traced to the Mediterranean basin; nay, some lived at the same time in Germany, England, and France, and were therefore probably distributed through all the European Cretaceous seas. By their occurrence at determinate epochs, the sea-urchins show that each stage had its peculiar species, which is manifest from what has already been stated. Indeed it appears that certain genera are confined to a definite division of the Cretaceous series: thus *Stenonia*, *Offaster*, *Pilula*, and *Ananchytes* occur only in the Upper Cretaceous, for which *Ananchytes ovatus*, Lam. (fig. 117), especially is a guiding fossil; it occurs in the Seewen limestone of

Unterwalden, on the Calanda and the Fähner, and has been observed almost everywhere in Europe where the White Chalk occurs. The *Ananchytæ* are large sea-urchins with similar ambulacral areas, of which the ambulacra do not unite in a petaloid form as in the other heart-urchins.

Mollusca furnish the main contingent towards the population of the Swiss Cretaceous sea. From the summary of the Cretaceous Cephalopods given at p. 183, it appears that in number of species they vie with the Cephalopods of the Jurassic sea (p. 132). The Belemnites, indeed, have already considerably diminished in number, and the Ammonites are not quite so numerous; but the *Nautili* have increased in number, and the Turrilites, Baculites, Ptychoceras, and Hamites form perfectly new genera; in fact the numerous straight Ammonitidæ with the extremities turned round or rolled are specially characteristic of the Cretaceous epoch. Even in the Jurassic sea this family had developed a wonderful variety of forms; and the transformation of the generic type continues throughout the Cretaceous epoch, and new types are also added. The separation of the spiral whorls of the shell still remaining in the same plane commenced in Jurassic times; and not only is this continued in the Cretaceous, not only do the shells acquire the forms of horns and straight rods, but they even become spirally twisted (*Turrilites*). Thus this remarkable type is displayed in every form.

The family of the *Cuttlefish* is more abundantly represented in the Alpine than in the Jurassic zone; and all the species which have hitherto been found in the latter occur also in the former. Most of them, however, are also found in the Mediterranean basin. The most abundant species is *Belemnites pistilliformis*, Bl., which characterizes the Neocomian stage.

The family of the Pearly Nautili (Nautilidæ) includes twenty-one species; and some of their shells are smooth, like those which have been already mentioned, whilst others are traversed by numerous, close, transverse ribs, a structure which first appears in the Cretaceous sea. *Nautilus neocomiensis*, D'Orb. (fig. 118), may serve as an example of this group; it occurs on the Sentis, at Sainte-Croix, and on the Salève, and it also inhabited the Mediterranean basin. These *Nautili* are not quite so large as those of the Jurassic epoch; but *N. bifurcatus*, Oost., from the Hohgant is about 6 inches in diameter; so that the *Nautili* were among the largest mollusks of the Cretaceous sea.

In the family of Ammonitidæ we find a series of genera, but in number of species the true Ammonites predominate. The species of this genus have undergone a complete transformation since the Jurassic period, not a single one being identical with any of the Jurassic species. Indeed several groups (such as the Arietes) have become extinct, whilst others (*e. g.* the Planulati, the Heterophylli, and the Macrocephali) are continued into the

Fig. 118.

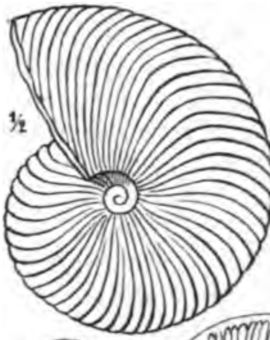


Fig. 119.

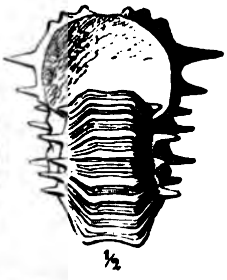
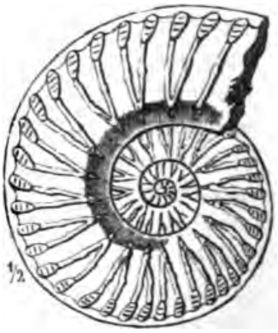


Fig. 120.



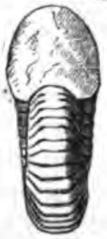


Fig. 121 *a*.

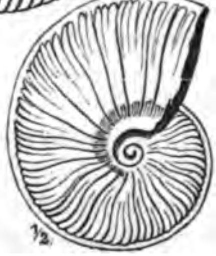


Fig. 122.

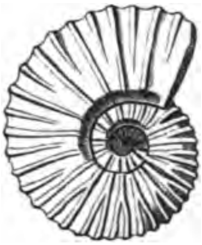


Fig. 121 *b*.

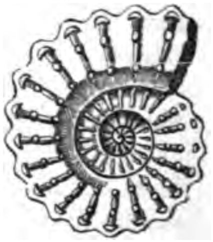


Fig. 123.

Fig. 118. *Nautilus neocomiensis*, D'Orb.
Fig. 119. *Ammonites mammillatus*, Schl.
Fig. 120. *Ammonites inflatus*, Sow.
Fig. 121. *Ammonites milletianus*, D'Orb.
Fig. 122. *Ammonites Hugardianus*, D'Orb.
Fig. 123. *Ammonites Lyellii*, Leym.

Cretaceous sea or represented there by very nearly allied forms; thus the Cristati, distinguished by their sharply keeled back, represent the Falciferi of the Jura. To these must be added the peculiarly Cretaceous groups, such as the Rhotomagenses and the Mammillati.

Some of the principal forms of the Swiss Cretaceous Ammonites are shown in figs. 119–123. *A. Hugardianus,* D'Orb. (fig. 122), and *A. inflatus,* Sow. (fig. 120), are representatives of the Cristati. The back has a sharp continuous keel; and the sides are traversed by curved bifurcate or trifurcate ribs. *A. Hugardianus* occurs in the Gault of the Jura and in the Alps of the Canton of Vaud and of Savoy; it has also been discovered in the Carpathians and the Caucasus, and even in Venezuela; so that it was probably distributed throughout the Cretaceous seas. *A. inflatus* also was widely diffused at the time of the Gault; it may be traced from the north side of the Sentis to the Canton of Vaud, and also lived on the Jurassic shore (at the Perte-du-Rhône and Sainte-Croix). *A. Lyellii,* Leym. (fig. 123), belongs to the group Rhotomagenses, in which the back bears a series of distinct tubercles instead of a keel. It is characterized by the seven rows of tubercles, which are very elegantly arranged upon the shell. It is also one of the widely distributed middle Cretaceous (Gault) species, being found in Switzerland on the western ridge of the Hinter-Glärnisch (the Nebelkäppler), on the Käserenalp in the Canton of Schwyz, in the Alps of the Canton of Vaud, and in the Jura (Sainte-Croix and Perte-du-Rhône). In the Mammillati the back is smooth, but bordered on each side by a row of tubercles. *A. mammillatus,* Schloth. (fig. 119), first appears in Switzerland in the Aptian (Perte-du-Rhône), but only attains its full development in the Gault (in the Alps of the Cantons of Berne and Schwyz and in the Toggenburg); it disappears during the Aptian stage in Switzerland and in France, but survives in England and Germany.

One of the groups with the greatest number of species is that of the Angulicostati, in which the sharp ribs are continued over the rounded or flat back. *Ammonites milletianus,* D'Orb. (fig. 121), is the most abundant species in the Jura and the Alps (found at the Kistenpass, on the Sentis, and in the Canton of Schwyz), and at the same time one of the species which may be traced into the south of France and through

Germany into the Franco-Britannic sea. It attains a large size; at the Perte-du-Rhône specimens 17 inches in diameter have been found. It is distinguished chiefly by its flat back, and its alternately long and short lateral ribs.

The Ligati are nearly allied to the Angulicostati; but in them the ribs become fainter or are converted into striæ on the rounded back, and sometimes are there deficient. Sometimes transverse furrows are found, indicating the positions of former apertures. *Ammonites ligatus*, D'Orb., is characteristic of the Swiss Alpine Neocomian (at the Stockhorn and Châtel St. Denis), and may be traced to the south of France and to Spain. *A. Mayorianus*, D'Orb., on the other hand, is one of the most widely distributed species of the Gault, and maintained its place in the Swiss Cretaceous sea until the formation of the Seewen limestone. It has been observed in the Alps of Appenzell and the Canton of Vaud, and at Sainte-Croix and the Perte-du-Rhône; it occurs not only in the south of France and in the Franco-Britannic sea, but also in the Carpathians and the Caucasus, and even in Venezuela. The compressed shell of this species is adorned with numerous transverse ribs, which become much fainter towards the centre of the shell, and is also traversed by from four to six curved furrows.

The series of unrolled Ammonitidæ is commenced by the Scaphites, in which the shell, at first closely coiled, afterwards becomes straight, but becomes rolled in again at the other end. *Scaphites Hugardianus*, D'Orb. (fig. 125), has an elegant shell, traversed by numerous transverse ribs; its bent and coiled extremities nearly touch each other. It occurs on the Sentis, on the Fähnern, in the upper valley of the Sihl, in the western Alps, and at the Perte-du-Rhône, and it is also met with in France, together with two other Alpine species (*S. Yvani*, Puz., and *S. æqualis*, Sow.).

The genus *Ancyloceras* is very similar; but the coiled extremities are here in separate turns, and the mouth part is only bent like a hook and not spirally coiled. This genus has thirty-five species, which form one of the chief beauties of the Neocomian fauna of the Stockhorn, and of Châtel St. Denis in the Canton of Fribourg. The majority of these species are wanting in Eastern Switzerland, in the Jura, and in the Paris basin, but reappear in the south of France. About a dozen species are peculiar to Châtel St. Denis and the Bernese Alps. Some of them (*A. Meriani* and *A. Escheri*, Oost.) are only marked with fine transverse striæ; others are adorned with sharp ribs (*A. Brunneri* and *A. Heerii*, Oost.) sometimes set with tubercles. In some species these tubercles are produced on the back into long and strong spines (as in *A. Honorati*, Oost., *A. Matheronianum*, D'Orb., fig. 124, and *A. Morloti*, Oost.). The thinner extremity is always elegantly coiled, and generally terminates in a fine point. They are of considerable size, one species (*A. gigas*, D'Orb.) sometimes attaining a length of 15 inches.

Fig. 124. Fig. 126. Fig. 127. Fig. 128.

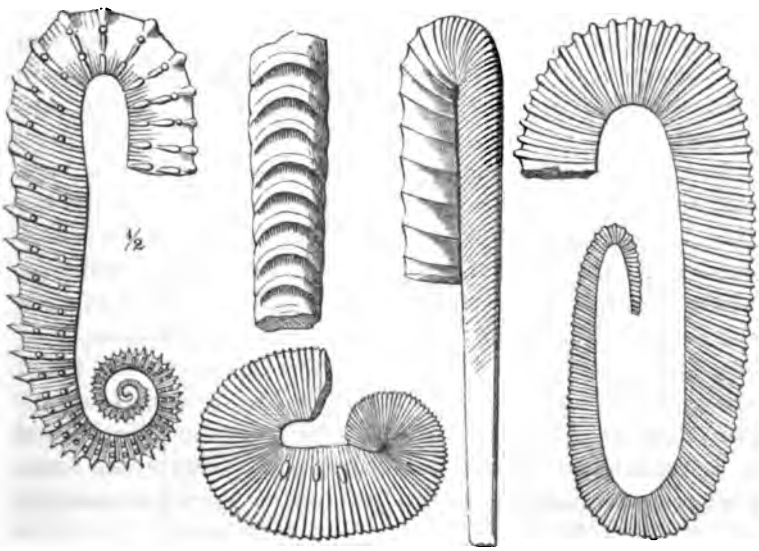


Fig. 125.

Fig. 124. *Ancyloceras Matheronianum*, D'Orb.
Fig. 125. *Scaphites Hugardianus*, D'Orb.
Fig. 126. *Baculites Gaudini*, Pict.
Fig. 127. *Ptychoceras Puzosianum*, D'Orb.
Fig. 128. *Hamites rotundus*, Sow.

The most widely distributed species is *A. Duvalii*, Art., which lived on both shores of the Swiss Cretaceous sea, and is also found in Germany, England, the south of France, Spain, and Algeria, and is even known in Chili.

In a group separated by Pictet under the name of *Anisoceras* the spiral end is curved so that it does not lie in the same plane as the rest of the shell. *A. Saussureanum*, Pict., which belongs to this group, and occurs near Saxonet and at the Perte-du-Rhône, is one of the largest animals of this family, sometimes reaching a length of about 2 feet.

The species of *Toxoceras* resemble obliquely curved horns with the ends neither coiled nor bent round, so that they look like goats' horns. They chiefly inhabited the Mediterranean basin, but extended thence into the Swiss Cretaceous sea. *Toxoceras Lardyi*, Pict., has been discovered at the Perte-du-Rhône, and a very similar species on the Altmann in Appenzell.

In the *Hamitæ* the shell forms a horseshoe-like hook at each end, the arms of these hooks being more or less parallel to the straight body of the shell; whilst in the *Hamulinæ* there is only one hook. The latter are rare and confined to the Neocomian, whilst numerous species of *Hamites* occur in the Gault of both the Jura and the Alps. The beautiful *Hamites rotundus*, Sow. (fig. 128), was distributed over the whole Cretaceous sea, which was also the case with several other species (such as *H. attenuatus*, Sow., *H. flexuosus*, Sow., and *H. Charpentieri*, Pict.); and it is remarkable that of this genus, as of *Nautilus*, the Swiss Cretaceous sea has comparatively numerous species in common with the Paris basin.

Whilst in *Hamites* the hooked portion remains free from the body of the shell, it is closely pressed to the latter in the genus *Ptychoceras*, or even inserted into a furrow of its surface. *Ptychoceras gaultinum*, Pict., occurs in the Gault of the Jura and of the Alps. *P. Puzosianum*, D'Orb. (fig. 127), and four other species belong to the Alpine Neocomian; so that this genus, like *Ancyloceras*, is characteristic of the Alpine zone; and most of its species belong also to the Mediterranean fauna.

In *Baculites* the Ammonite type has become converted into a perfectly straight or but slightly curved rod, the spiral or hook-like curves being entirely deficient. These belong exclusively to the Cretaceous sea, commencing in the Neocomian and becoming extinct with the Upper Cretaceous. Fig. 126 represents only a fragment of ***Baculites Gaudini***, Pict.; its shell terminates in a fine point. This species has been found in many places in the Alps (on the Sentis, in the Tamina valley, on the Käserenalp near Cheville, and in the Valais), and also in the Jura (Sainte-Croix and the Perte-du-Rhône); it also occurs in Savoy and in England. ***B. baculoides***, Mont., sp., had a similar distribution, whilst the other species lived within narrower limits.

The *Turrilites* resemble ordinary spiral shells in their form; but the interior is divided into chambers by septa as in the Ammonites. They constitute the last peculiar modification of the Ammonite type; for (with the exception of a few curious species which form a distinct group) they only commence in the Gault, and vanish at the close of the Cretaceous epoch; so that

Fig. 129.

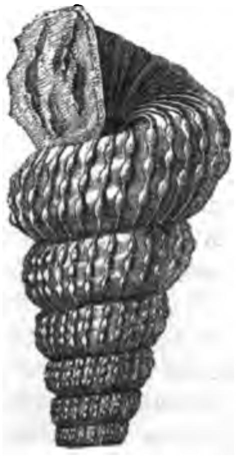
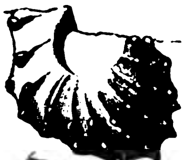


Fig. 130.



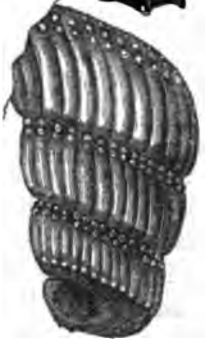


Fig. 131.

Fig. 129. *Turrilites Bergeri*, Br.
Fig. 130. The same, from the Kistenpass.
Fig. 131. *Turrilites Puzosianus*, D'Orb., from the Neualpkamm.

this genus merely lasted for a short time. Nevertheless it developed into numerous species (about fifty), eighteen of which inhabited the Swiss Cretaceous sea. As in many Ammonites, the shells are adorned with tubercles and ridges; and the latter are either longitudinal or transverse, and are often set with elegant bosses. The most abundant species is *Turrilites Bergeri*, Br. (fig. 129), which occurs in the Cretaceous rocks in many places in the Alps (as on the Sentis, at the summit of the Kistenpass, fig. 130, at the Silbern, the Pragel, the Rossmatt, the Vettiseralp, the Col de Cheville, and in the Valais), and in the Jura in the Gault and the Seewen limestone. It has also been found in Savoy and the south of France, in the Paris basin, and in England. *T. costatus*, D'Orb., discovered by Escher de la Linth on the Sentis, has the same distribution. Most of the other species, however, are common only to the Swiss fauna and to the Mediterranean basin; among these is *T. Puzosianus*, D'Orb., of which fig 131 represents a specimen from the Neualpkamm in Toggenburg. In this species the shell is marked with strongly projecting transverse ribs; in *T. Bergeri*, on the contrary, the transverse ribs are faint, but each of them bears four bosses, so arranged that they form four rows on each whorl. There are tubercles on *T. Puzosianus* also; but they are small and placed close to the margins of the whorls.

When we glance at the other marine univalves, we find in part the same genera with which we were familiar in the Jurassic sea, and also some new types. The genus *Pterocera* offers us several beautiful species with the border of the lip divided into finger-like processes (such as *P. Rachatiana*, D'Orb.) at the Perte-du-Rhône, and a very large species (*R. pelagi*, Br.) in the Urgonian of the Alps and in the Jurassic zone. The nearly allied genus *Rostellaria* first appears in the Cretaceous period, and has continued into the seas of the present time; it has the lobes of the wing-like margin less deep than in *Pterocera*; several species of this genus (*R. Orbygniana*, Pict., and *R. Robinaldiana*, Pict.) occur in the Jurassic zone.

The *Nerineæ* are less abundant than in the Jurassic sea; but they appear in equally large and remarkable forms, possessing conical shells with sharply marked whorls. Associated with numerous *Naticæ* (*N. rotundata*, Sow., *N. Clementina*, D'Orb., *N. Rauliniana*, Pict., and many others) we find the nearly allied genus *Narica*, with a spherical spirally striated shell, a few species of which still exist in tropical seas. At the time of the Gault there was one species (*N. genevensis*, Pict.) at the Perte-du-Rhône. The genera *Trochus, Turbo,* and *Cerithium,* with which we have already made acquaintance (p. 136), include many species which inhabited the Swiss Cretaceous sea, and the occurrence of which indicates the vicinity of the coast.

Of the vast multitude of bivalve shells of the Swiss Cretaceous period, we must confine ourselves to a few of the most important forms. We meet once more, for the most part, with the same genera which inhabited the Jurassic sea (see p. 136), such as *Terebratula, Astarte, Cardita, Diceras, Lyriodon, Inoceramus, Pecten, Lima, Exogyra, Gryphæa, Ostrea,* &c. Many of the species differ so widely from those of the earlier period as to form groups peculiar to the Cretaceous epoch.

In most of the Oysters of this period the shells are traversed by narrow strongly projecting folds, which interlock in a zigzag fashion at the margin of the two valves. *Ostrea macroptera,* D'Orb. (fig. 132), is a fine example of the "Cock's-comb Oysters" of the Swiss Cretaceous sea. Its shells are about 3 inches long, curved and traversed by sharp ribs; and their zigzag margins fit into one another so accurately that one can hardly detect the

Fig. 132.

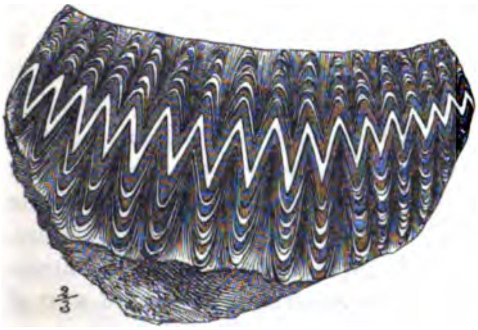


Fig. 133.

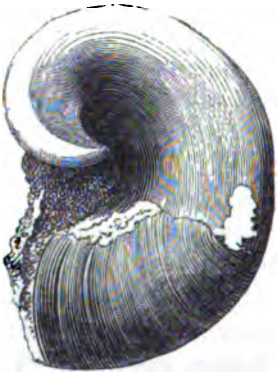


Fig. 132. *Ostrea macroptera,* D'Orb., from the glacier of the middle Glärnisch, two thirds nat. size.

Fig. 133. *Requienia ammonia,* Goldf., sp., from the Sentis.

line of separation. It was remarkably abundant in Neocomian times, and forms thick beds high up on the Glärnisch. The great glacier seen from Schwanden and Mitlödi rests upon a calcareous rock consisting of thousands of oysters, affording evidence that formerly the sea washed a great oyster-bed at this place. It has also been observed in the Alps of Appenzell and in the Jura. *Ostrea Couloni*, Def., has a similar distribution; it has been found in the Firenbänder of the Glärnisch, at the Wallenberg (near the Gäsi), and in many parts of the Appenzell Alps, as well as in the region of the Jura.

The bivalve fauna of the Cretaceous period is particularly characterized by the family Rudista, which is absolutely peculiar to it, commencing in the Neocomian and disappearing again in the Upper Cretaceous. This family differs in the structure of the shell so much from all other bivalves, that it is difficult to arrange it in the system; but it appears to belong to the Brachiopoda. The Rudista have two thick shells of unequal size, formed of two layers: the outside is laminar or fibrous; and the inner layer is perforated. The larger valve is attached to the ground by its pointed end, or frequently by its side; whilst the smaller valve covers the opening of the large one like a lid, but is not united to it by a hinge. The cavity is divided by longitudinal folds and lateral lobate processes, and at the bottom is not uncommonly filled up by irregular transverse partitions. In some (Hippuritidæ) the large valve is straight and conical; in others (Caprinidæ) the shells are spirally curved and acquire the form of goats' horns. These animals lived associated in great multitudes; and thus they form here and there whole rock masses, whilst they are entirely wanting in other localities. The Hippurites, which occur in great quantities on the Untersberg in Salzburg and at Gosau in Austria, in the south-west of France, and in the Pyrenees, have not yet been found in Switzerland; but the Caprinidæ are exceedingly abundant in the Urgonian of the Alps, especially *Requienia* (*Caprotina*) *ammonia*, Goldf., sp. (fig. 133), the shell of which was oblique, smooth, spirally twisted, traversed by two longitudinal furrows, and attached by one side. This is a characteristic shell of the Urgonian stage of the Cretaceous formation in both the Alps and the Jura, and formed extensive shell-beds on all the Swiss Cretaceous coasts; here and there it was associated with a second, similar species (*R. Lonsdalii*, D'Orb.) and with a *Radiolites* (*R. neocomiensis*, D'Orb.).

The *Bryozoa* (or Polyzoa) constitute a peculiar section of the Mollusca. They live in great societies and form common stocks like the Polypes, which they resemble also in having the mouth surrounded by tentacles; but in their internal organization they differ so much from the Polypes that they have been separated from them and placed among the Mollusca. The calcareous dwellings of these animals are frequently found in the Swiss Cretaceous deposits. Loriol has described, from the Neocomian of the Salève, 23 species belonging to 20 genera of Bryozoa. One of the most abundant species is *Multicavea neocomiensis*, Lor.; it forms little bushes, the numerous cylindrical branches of which are covered externally with small pores representing the apertures of the tubular cells formerly inhabited by the delicate little animals.

The Swiss Cretaceous sea had a remarkably scanty supply of Crustacea. Only a very few Swiss species are known; and of these a Crab with a broad carapace, slightly emarginate in front (*Xantho Fischeri*, Milne-Edw.), from the Gault of Sainte-Croix, deserves to be noticed. Fishes and Reptiles, also, do not seem to have been plentiful, although their remains occur here and there. Among the Fishes the Sharks are particularly worthy of notice, as six species of them swam about in the Swiss Cretaceous sea, belonging to genera some of which (such as *Oxyrrhina* and *Odontaspis*) are still living, whilst others (*Otodus* and *Corax*) specially belonged to the Cretaceous and Tertiary seas. Of the Ganoids we find, as in the Jurassic period, the genus *Pycnodus*, which is represented here by five species; one of these (*P. Münsteri*, Ag.) has been found on the Sentis (in the Urgonian), and also at the Perte-du-Rhône and on the Salève, whilst another (*P. Couloni*, Ag.) is abundant in the Neocomian of the Jura. We have also the Ganoid genera *Sphenodus* and *Gyrodus*, with small, round, umbilicated teeth. From the Neocomian of the Voirons, Pictet has described four Clupeoid fish, one of which (*Clupea voironensis*, Pict.) most resembles the true Herring, and another (*C. antiqua*, Pict.) the Shad (*C. alosa*), whilst the remaining two species form genera peculiar to the Cretaceous formation (*Spathodactylus neocomiensis*, Pict., and *Crassognathus sabaudianus*, Pict.), the nearest allies of which are the tropical genera *Elops* and *Megalops*. By these Herrings and Sharks, the Cretaceous fishes approach those of the present day, and depart widely from the fishes of the Jurassic sea.

That Crocodiles and Plesiosaurs visited the Swiss Cretaceous coasts is shown by the teeth which have been found at Sainte-Croix and the Perte-du-Rhône. But they seem to have been only small species, whilst at that time other regions of the sea still harboured gigantic Saurians. Thus *Mosasaurus Hofmanni*, Camp., sp., from the celebrated quarries of St. Peter's Mount, near Maestricht, attained a length of about 26 feet; and the *Macrosaurus* appears to have been of equal dimensions. Two large species of marine turtles have been found at Sainte-Croix, the *Chelonia valenginiensis*, Pict., and *Trachyaspis Sancti Crucis*, Pict.: they had attained a considerable size.

THE LAND FLORA OF THE CRETACEOUS PERIOD.

No land plants of the Cretaceous period have been as yet discovered in Switzerland, although the land which surrounded the Swiss Cretaceous sea was no doubt covered with trees and bushes. Fortunately, in other countries, spots have been discovered in which such terrestrial plants have been preserved. They are indeed everywhere rare, and thus our knowledge of the Cretaceous flora is still very imperfect; but they nevertheless serve, to a certain extent, to clear up the obscurity which until recently veiled the Cretaceous continent. The places where these land plants have been discovered are shown on the map (fig. 98, p. 175) by a little cross (+). By far the most important is at Aix-la-Chapelle, where Dr. Debey has collected about 400 species of plants from a shore-formation. Some species are also found in the Harz (especially in the freestone of Blankenberg), in the neighbourhood of Halden and of Sonderhorst in Westphalia, in Saxony (Pillnitz and Niederschona), in numerous localities of Bohemia, in Moravia (Moletein) and Silesia (Oppeln and Tiefenfurth), also at Neustadt near Vienna, and at

Trieste. All these localities belong to the Upper Cretaceous series *.

No Cretaceous land plants are known in Germany from the Valangian stage upwards to the Cenomanian; but they occur in the Wernsdorff beds of the northern Carpathians, which belong to the Urgonian stage, and some species of pines have been discovered in Hainault, and in England, in the Greensand and Gault. In the Wealden formation † of the south-east of England and north-west of Germany, however, some important accumulations of plants have been discovered; and as the position of this formation is intermediate between the uppermost Jurassic and the lowest Cretaceous stages (probably representing the Valangian), these plants give us some notion of the flora of that period of transition from the Jura to the Cretaceous, during which dry land attained its greatest extension in Europe, whilst the other localities already mentioned display a more recent Cretaceous flora. The Wealden flora is more nearly related to that of the Upper White Jura than to the Upper Cretaceous flora; for the Wealden is separated from the Upper Cretaceous by a very long interval of time, during which the deposits of the various stages of the Lower and Middle Cretaceous series were formed.

Leafy trees do not occur in the Wealden; the forests were still, as in the Jurassic period, composed of Cycads and Conifers. Among the former we find seven species of *Pterophyllum*, and species of *Zamites* with rigid pinnate leaves,—and among the latter some Arbores vitæ, the *Thuites Germari* and *T. imbricatus*, Dunk., *Widdringtonites Kurrianus*, Dunk., sp., and various species of Pines and Firs*. Ferns constitute the family with the greatest number of species in the Cretaceous period; and their genera are for the most part analogous to those of the Jurassic period.

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* The plants from Saxony and Moravia probably belong to the first stage of the Upper Cretaceous, and those of Aix-la-Chapelle to the Senonian.

† The Wealden is indicated on the map (fig. 98, p. 175) by a line south of London comprising part of South-eastern England, and probably extending across what is now the British Channel into the neighbourhood of Boulogne, so as to form a tract of land of about 200 miles from west to east. In North-western Germany the Wealden has been ascertained to exist over an extent of about 165 miles, in the principality of Bückeburg, the county of Schaumburg, and in the Teutoburgerwald near Osnabrück, Minden, &c. The Wealden is a freshwater formation, the upper and lower beds of which, however, alternate with marine deposits. At the Wealden period there was dry land in places which had previously been under the waters of the Jurassic and Cretaceous seas; and this land formed a continent uniting the Atlantic continent with that of Central Europe.

The great majority of the forms of the Ferns are quite foreign to the existing European flora; but the Pines and Firs approach towards the modern flora, and the Equisetaceæ no longer appear in the large arborescent size of earlier periods, but as species which had nearly the same characteristics with those now existing. One of the horsetails possessed root-tubercles † exactly like those of the *Equisetum arvense* of the present day.

In the Lower Cretaceous series leafy trees are not found; none have yet been met with in the Wernsdorf (Urgonian) beds ‡. These beds contain Cycadeæ with fine leaves (*Pterophyllum Buchianum*, Ett., *Zamites Zittelii*, Schenk, *Z. Hoheneggeri*, Schenk, *Z. ovatus*, Schenk, *Z. pachyneurus*, Schenk, *Cycadites Heerii*, Schenk), several Coniferæ (*Pinus*, *Sequoia*, *Frenelopsis*), and, finally, Ferns.

Hainault, in Belgium, was rich in Coniferæ; we find there magnificent cones of Cedars, Pines, and Firs, some of which resemble those of existing species. Several species of the genus *Pinus* have also been discovered in the Greensand and Gault of England. The most interesting locality for the Lower Cretaceous flora is at the north of the peninsula of Noursoak in Greenland, in 70° 33′ N. lat. and 52° W. long. § Prof. Heer has shown that the black shales which immediately overlie the gneiss on the northern side of Noursoak belong to the Urgonian stage of the Lower Cretaceous formation. In his 'Arctic Fossil Flora,' he has described from these shales 75 species of plants and 2 or 3 insects. Of the plants, 38 belong to the Ferns, 1 to *Lycopodium*, 3 to the Equisetaceæ, 9 to the Cycadeæ, 17 to the Coniferæ, 6 to the Monocotyledons, and 1 to the Dicotyledons. The ferns consequently form the richest order; and at the same time they occur in great numbers of individuals: many slabs of rock are completely filled with such ferns, some of which are beautifully preserved. They belong to 15 genera, 5 of which (namely *Asplenium*, *Gleichenia*, *Oleandra*, *Adiantum*, and *Osmunda*) are still extant. The genus richest in species is *Gleichenia*, of which 13 species occur. This circumstance is the more remarkable as *Gleichenia* at present has its chief seat within the tropics and in the southern hemisphere, and not a single species of it occurs in the temperate zone of the northern hemisphere. Moreover there is at present no spot on the earth where so many species of *Gleichenia* occur in such close juxtaposition as they were in North Greenland in Lower Cretaceous times. Here in all probability there was a centre of origin for this genus.

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* In the south-west of the Isle of Wight numerous stems of trees from the Wealden lie on the shore, and are washed by the sea. Among them are found cones, some of which belong to the group of Firs and the others to the group of Pines. Dunker has figured the leaves of a pine (*Pinus Linkii*, Röm., sp.) which occur near Duingen, at the Deister, and at Osterwald in such masses as to form almost the whole deposit. See Dunker, 'Monographie der norddeutschen Wealdenbildung,' p. 19.

† Dunker has erroneously regarded these tubercles as fruits, and figured them under the name of *Carpolithes sertum* (*op. cit.* pl. vii. fig. 3). They probably belong to the *Equisetum Burchardi*, Dunk.

‡ See Schenk, "Die fossilen Pflanzen der Wernsdorfer Schichten in den Nordkarpathen," Palæontographica, 1869.

§ See Prof. Heer's 'Flore fossile des pays polaires,' i. p. 78.

As regards their distribution, the Cycadeæ nearly agree with the *Gleicheniæ*; they also chiefly belong to the Tropics, beyond which only a few species are to be met with. They are likewise more abundant in the southern than in the northern hemisphere. In the Lower Cretaceous rocks of Greenland they are plentiful, and constitute 4 distinct genera (*Zamites*, *Pterophyllum*, *Glossozamites*, *Anomozamites*). They were probably trees with simple cylindrical trunks, adorned with a crown of pinnate leaves.

A third very important element in the Cretaceous flora of Greenland is formed by the Coniferæ, which, with their 17 species and 8 genera, must have occupied an important position in the formation of the forests. Among the conifers the Mammoth-trees (*Sequoia*) are remarkable for number of species and frequency of occurrence; so that for this genus also North Greenland may be indicated as a centre of origin. Whilst Prof. Heer now knows only two living species (from California), he has obtained from the Lower Cretaceous of Greenland the twigs and cones of five species. That Pines and Firs likewise made their appearance very early in the high northern regions is shown by the six species of *Pinus,* one of which (*Pinus Crameri*) was among the most abundant trees of Greenland, its needles lying in some places by thousands in the slabs of rock. With these genera are to be associated *Glyptostrobus* and *Torreya,* isolated species of which are still in existence; whilst *Frenelopsis, Trolepis,* and *Cyparissidium* are peculiar extinct genera.

The Monocotyledons are scarce; and of the great class of true Dicotyledons (Angiosperms), only a single species of Poplar has been discovered, and this is represented only by one or two leaves. This Poplar (*Populus primæva,* Heer) is the oldest known Dicotyledonous plant.

The flora of the Lower Cretaceous in the Arctic zone has, therefore, the same character as in Europe. It consists principally of Ferns, Cycadeæ, and Coniferæ, in this respect closely approaching the flora of the Wealden and the Jura. On the other hand, the flora of the *Upper Cretaceous* is very different; and this is the case even in its lowest stage, the Cenomanian, as presented to Prof. Heer in Saxony, Bohemia, and Moravia, and also in the southern states of North America and in Greenland. In the Upper Cretaceous of Saxony, Bohemia, and Moravia, a good many Ferns and Coniferæ are still met with; and some of the species are common to the Lower Cretaceous—as, among ferns, *Gleichenia Zippei,* and, among the Coniferæ, *Sequoia Reichenbachi,* the latter being one of the most abundant and widely distributed trees of the Cretaceous epoch, and traceable from Central Europe to Greenland and Spitzbergen. The *Gleicheniæ,* however, became much scarcer in the Upper Cretaceous; and this remark applies also to the Cycadeæ. But what most distinguishes the Upper Cretaceous flora, and gives it a different character in comparison with the older floras, is the occurrence and rich development of the true Angiospermous Dicotyledons. In the Cenomanian of Moletein, in Moravia, 8 families of these Dicotyledons are found, which constitute two thirds of the plants hitherto found within that locality. Most of them belong to the Apetalæ (*Ficus, Juglans, Daphnophyllum, Credneria*); but Polypetalæ also occur, and, indeed, Araliaceæ, Myrtaceæ, and

Magnoliæ,—the last characterized by their fine, large, coriaceous leaves and thick fruit cones, reminding Prof. Heer of the living *Magnolia grandiflora*. The *Credneria macrophylla* had still larger leaves; and several fine species of this genus have been found near Blaurenburg, in the Hartz. In the sandstones of Bohemia and Saxony Dicotyledons appear with a whole series of species, belonging to very different families. The same phenomena are repeated in the higher stages of the Cretaceous, which have received the names of Turonian and Senonian. From the Senonian marls of Quedlinberg Prof. Heer has obtained 20 species of plants, 10 of which are Dicotyledons: among them are 1 *Salix*, 2 *Myricæ*, and 1 *Rhus*. The Senonian deposits of Aix-la-Chapelle are much richer, about 200 Dicotyledons being recorded from them.

That this great change in the flora took place not only in the Cenomanian of Europe, but also in America, is shown by the rich collections of fossil plants which have lately been made in the western territories of the United States, and described by Prof. L. Lesquereux*. He distinguishes 130 species, about 100 of which are Dicotyledons. These consequently form the great mass of the species, which are divisible into numerous genera, of which the following may be particularly noticed:—*Fagus, Quercus, Platanus, Ficus, Sassafras, Diospyros, Andromeda, Liriodendron*, and *Magnolia*. The greater part of the species belong to the Apetalæ (61); but the Polypetalæ are numerous (35), and even the Gamopetalæ are represented (5).

Recently Prof. Heer has received some plants from the Upper Cretaceous of Tropical Africa. These were found by Dr. Schweinfurth at the oasis of Chargeh, west of Thebes, in strata containing marine Upper Cretaceous fossils, including *Ananchites ovatus*, a Sea-urchin, represented in fig. 117, p. 215, from the Seewen limestone. The fruits enable Prof. Heer to recognize a Palm and two Ebenaceæ (*Diospyros* and *Rogeria*), so that even among the Cretaceous plants of Tropical Africa Dicotyledons appear exactly as among those of Europe, America, and Greenland; and, singularly enough, the genus *Diospyros* is again met with. This genus must therefore hold a peculiar and important place in the developmental history of the vegetable world.

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* Contributions to the Fossil Flora of the Western Territories of the United States. I. Cretaceous Flora. Washington: 1874.

It has been observed that the flora of the Lower Cretaceous of Greenland has the same character as that of Europe at the same time. With respect to the Upper Cretaceous flora of Greenland, Prof. Nordenskiöld has discovered on the south side of the Noursoak peninsula a flora belonging to the Cenomanian, described by Prof. Heer in the third volume of his 'Flora Fossilis Arctica.' It consists of 65 species, of which 15 belong to the Ferns, 2 to the Cycadeæ, 11 to the Coniferæ, 3 to the Monocotyledons, and 34 to the Dicotyledons. Of the Ferns, the *Gleicheniæ* have become scarce, and the tropical genus *Oleandra* has disappeared; but at Disco the thick stems of a remarkable tree fern (*Protopteris punctata*, Sternb., sp.) occur, a species which has also been found in England (in the Upper Greensand of Shaftesbury, Dorsetshire), as well as in Silesia, Saxony, and Bohemia. The Cycadeæ are few in number; and the species of *Zamites*, so abundant in the Lower Cretaceous of Greenland, entirely disappear. On the other hand, Coniferæ are abundant, the *Sequoiæ* being the most frequently met with. But, as in the Upper Cretaceous of Europe and North America, the Dicotyledons become the most abundant plants, and they appear in generic types belonging to different families. Prof. Heer finds among them *Populus, Myrica, Ficus* (in leaves and fruit-cups), *Sassafras, Andromeda, Diospyros, Myrsine, Panax, Magnoliæ,* Myrtles, and Leguminosæ. Thus, in the high northern regions, the same great change of the flora took place as in Central Europe and North America, and the Dicotyledons appear in a whole series of widely divergent genera belonging to the Apetalæ, Polypetalæ, and Gamopetalæ, and in part agreeing with those of the European and American Upper Cretaceous.

The entire absence of the Angiospermous Dicotyledons in all divisions of the Jurassic series of all countries, and up to the Wealden and Necomian in the Lower Cretaceous, the first feeble indication of them in the Urgonian, and their sudden abundant development in the lowest stage of the Upper Cretaceous (the Cenomanian), from the tropics to the arctic zone, certainly forms one of the most important phenomena in the history of the development of nature.

Returning now from this general glance at the world of plants which clothed our planet in the Cretaceous period, we may say that the islands which stood out from the sea in Neocomian and Urgonian (Lower Cretaceous) times were very probably covered with Cycadeæ and Coniferæ, among which were numerous plants belonging to species of *Zamites* and *Sequoiæ*. This view has been recently confirmed, as Prof. Heer has obtained from the Neocomian of the top of the Seelisberg, on the Lake of the Four Cantons, the leaves of a species of *Zamites*. In the shade of these forests lived the Ferns, among which the *Gleicheniæ* probably occupied the chief place.

At the time when the Seewen limestone (the Upper Cretaceous) was deposited, a great change had taken place in the flora. Leafy trees had made their appearance, and the Poplars, Fig-trees, *Diospyros* and *Magnoliæ*, Laurels and Myrtles, must have given a different aspect to the landscape.

With these leafy trees there appears among the Dicotyledons a profusion of new types of plants, which, in the following (Eocene) period attained their full development, and at the present day continue to give a character to rural scenery.

CHAPTER VI.

EOCENE FORMATION.

Slate-Quarries of Matt, in the Canton of Glaris.

If we stop at Wesen, on the railroad from Zurich to Coire, a valley opens to the right, apparently of limited extent; and if we penetrate into it, we find it covered with luxuriant fields and meadows, and enlivened with prosperous villages.

The mountains rising from this valley shoot up in bold limestone walls and steep precipices. Near Schwanden the valley divides into two long alpine valleys, from the eastern of which flows the Sernf, and from the western the Linth, still in its early course. The valley of the Linth is also called, from its larger size, the large valley, and the valley of the Sernf receives the name of the little valley. The larger valley rises gently as far as the Linththal, and is adorned with meadows; but in the Thierfehd, about an hour's walk further on, the colossal mountains approach each other so closely that the river Linth becomes confined within a narrow rocky gorge. The limestone mountains which form the left side and the upper end of the Linth valley are the middle Glärnisch and the Bächistock, the rocky pyramid of the Selbsanft, and the majestic Tödi.

The valley of the Sernf, which lies in a crescent-shape round the foot of the Freiberg, has a very different appearance. Even at its entrance the mountains on both sides of the valley are so close together that, for a distance of three miles, the Sernf rushes through a deep ravine; and it is only near Engi that the mountains on the two sides separate sufficiently to leave room for a narrow and very irregular glen. Over this are scattered the houses forming the village of Engi, belonging to the parish of Matt; they are about 800 feet above Schwanden. Around Matt high mountains rise with gentle slopes, the crests and peaks undergoing the process of disintegration. These mountains are traversed by numerous furrows, which, at the foot, become converted into deep gorges, through which, during storms and heavy rains, the brooks convey immense quantities of mud and débris to the valley; the slopes are here and there devastated by landslips and by destructive torrents, which almost every year alarm the inhabitants of the valley. The accumulation of débris piled up at the openings of the lateral valleys afford evidence of the frequent action of water on the hills for many thousands of years. At the same time, as the rock readily weathers, the soil is very fertile: it is particularly well suited to the growth of trees; and magnificent forests extend up into the lower Alps; fresh green meadows cover the valley bottom; and rich Alpine pastures spread over the slopes and broad mountain-terraces. In the high Alpine regions of this district, where the stunted vegetation can no longer hold its ground against the constant disintegration of the rock, a vast extent of country is covered with débris and becomes a desert.

Such is the character of the mountains furnishing the Glaris slates, which are exported far and wide for the covering of houses and for writing-slates. They are worked in the neighbourhood of the village of Engi. When we reach the last houses in Engi, on the way to Matt, we hear high up on both sides of the valley a loud hammering and knocking in the slate-quarries; and on ascending towards the place from which we hear the loudest hammering, we come in about half an hour to the quarry called "An der Eck," 2970 feet above the level of the sea, and we there overlook thirty or forty working-places of quarrymen, whose multifarious occupations present an animated scene. In one place a deep channel is cut into the rock in order to separate a part of it; in another portion of the quarry, iron wedges are driven in between the beds to detach them from the main rock; and in other places, again, we see how the large slabs are lifted up and removed, or cut into smaller pieces. Each slab has a definite natural thickness; and according to this thickness and the nature of the slate it is selected for various practical purposes. The thickest slabs are used for paving kitchens, cellars, and passages; thinner slabs are employed for roofing, and the finest pieces for writing-slates, tables, and the tops of stoves. Each slab has a rough side, with a calcareous and siliceous grain, and a smooth and argillaceous side. In both the quarries the smooth part lies below and the rough side above; but in the rocks lower down, on both sides of the valley, the rough part of the slab is below and the smooth part above; so that here, no doubt, the strata have been inverted—an hypothesis which is confirmed by a bend in the rock visible at the north-western angle of the old quarry.

It is remarkable that the slabs are only cleavable in the higher beds, and not in the lower rocks, where the smooth part is uppermost; so that the lower strata cannot be worked. In the older quarries the separation of the slates is more easy, while in the new quarries the splitting is more difficult and causes increased expenditure both in time and money.

Slates similar to those of Engi occur in several parts of the valley of the Sernf, as above Matt in the Weid and on the Geissstafel, where they are remarkable for their softness, and are employed for making pencils; a similar kind occurs on the Bergli Alp and in the Unterthal near Elm. Slates appear in the valley of the Linth on the right side, near Betschwanden, and are probably the continuation of the deposit at Engi. The same formation, known as *Flysch*, occurs at several places on the northern slope of the Alps and in some other Cantons; but the only deposits which have been found worth working are near Pfäffers, at Mühlenen, at the foot of the Niesen, and near Interlaken. These slates cannot, however, be split into such fine smooth laminæ as those of the Glaris quarries, and they do not present one rough and one soft side.

The Plattenberg of Matt is renowned in Switzerland for its writing- and roofing-slates, and in scientific circles for its numerous fossils. It is one of the localities which lighten up the primæval history of Switzerland. Traces of plants, Mollusca, and Radiata have not as yet been found there; but it contains so great an abundance of fishes that it has become the most important Swiss locality for the remains of fossil fish.

The absence of the lower forms of animals and of plants cannot be accidental; for they have been looked for during many years, and, considering the immense quantity of slabs which have been extracted, they must have been observed if they had formerly lived in this region of the sea. Probably the sea was very deep at this spot; and the sea-bottom must have consisted of soft mud, which is proved by the slates formed from it. For this reason no plants could live here, nor could Mollusca or Sea-urchins continue in life. The mode in which fishes have been preserved is also in accordance with this view of the great depth of the sea. Their scaly covering is entirely deficient, and in general no fish-scales are found in the slates of Matt. In part, no doubt, this is due to the fact that the most abundant of the fishes had no scales, or very small ones; but many, such as the Herrings and Smelts, certainly possessed a scaly covering. It is also remarkable that the feathers of the birds are wanting, and that in the turtles the scales of the feet have disappeared. The cause of this must evidently be a local one. If the sea was very deep at this point, the dead birds, turtles, and fishes would at first have been driven about upon the water until decomposition set in, when their scales and feathers would gradually fall off; and as the process of decomposition became further advanced, the dead animals would sink down and slowly reach the bottom of the sea, where they would be buried in the mud. Only those fishes which had a very thick leathery skin, cuirassed with large plates firmly united at the edges (*Acanthosoma* and *Acanthopleurus*), retained their tough covering until they reached the bottom, whilst of all the other fishes, which possessed a softer and more destructible skin, nothing was preserved except the skeleton.

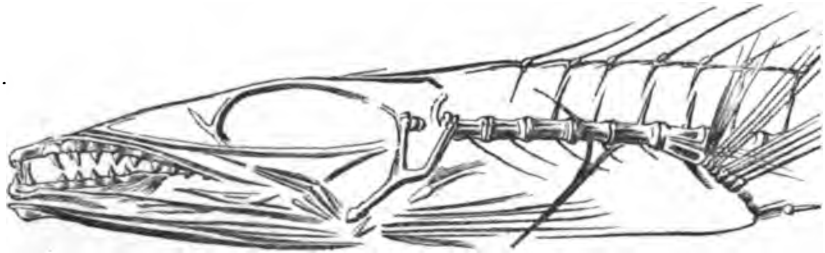
Generally speaking, the skeleton is perfectly preserved; for, although the head is frequently wanting and sometimes the tail, or the skeleton is broken in the middle, many specimens are quite perfect; and even in the incomplete or broken specimens the five ribs and ossicles, and the delicate rays of the fins, have generally retained their natural position. Hence the deposit cannot have been formed on a shore exposed to the surf or in shallow water; otherwise the fishes would have been completely broken up if their envelopment had taken place so slowly as to give time for the loss of all their scales. Thus it seems to Prof. Heer that the assumption of very deep water with a muddy bottom, in which envelopment took place very slowly, explains the peculiar character of the fishes of Matt, and also accounts for the absence of marine algæ and of sea-shore animals.

Dry land was at no great distance, which is shown by the two species of birds found at Matt. But we may easily suppose that an arm of the sea with a very deep bottom penetrated far into the land at this point, and that the shores rose steeply from the water. The entire absence of rolled pebbles in this slate, the fine grain of the stone, and the uniform thickness of the beds indicate that in this locality no rivers or brooks from the region of the Alps flowed into the sea.

We must now examine the animals themselves, and see to what conclusions we are led with respect to the mode of life of their nearest relations among existing species. Fifty-seven species have been recognized—namely, 53 Fishes, 2 Turtles, and 2 Birds. Of the Fishes, 6 species and 4 genera are still doubtful, and may be left out of consideration. The other 47 species belong to 19 genera, 4 of which (*Fistularia, Vomer, Osmerus,* and *Clupea*) still exist; the others are extinct, but 8 of them (with 27 species) come very near to existing genera; so that in general character the greater part of the fishes of Matt agree with living forms, although nearly four fifths of the genera are extinct and peculiar to this locality. These fishes are much more nearly allied to those of the present day than to the fishes of the Jurassic sea. In the latter the greater part of the species are Ganoids; but in the Cretaceous period these decrease in importance, and very few of them are now living. In Cretaceous times the Acanthopterygii appeared; and these constitute four fifths of the species at Matt. Agassiz first showed that a great change in the development of the fish type had occurred during the Cretaceous epoch, and that at the time of the formation of the slates of Matt the type appeared under new forms, some of which have partly continued to the present day. The Malacopterygii and Plectognathi, which were entirely deficient in former periods, are added to the Acanthopterygii.

The Acanthopterygian family which includes the largest number of species is that of the Scomberidæ (Mackerels, Tunnies, &c.); and two genera of this family (*Palæorhynchum* and *Anenchelum*), including 15 species, furnish by far the greater part of the fish-impressions of Matt. These fishes are easily recognized: they are very long, ribbon-like fishes; and their skin was covered with a silvery powder, but not with true scales. In the *Anenchelum* (fig. 135) we find a small head, narrowed in front, the jaws of which are partly provided with large and partly with small teeth. The vertebral column is very long, and consists generally of 110 to 112 vertebræ, bearing their ribs directed backwards, which join the interspinous ossicles bearing the dorsal fin. These ossicles combine to form a horizontal line, so that a bony ridge is produced along both the dorsal and ventral margins. As the fishes are very long and narrow, the two ridges run parallel for a certain space. The dorsal fin, which is seated upon the dorsal ridge, extends from head to tail, and is of nearly the same height throughout. On the ventral edge we find a similar but shorter and narrower fin (the anal fin), which only fringes part of the tail. The ventral fin is large and composed of strong rays. At the caudal extremity the body is much narrowed, and bears a very wide forked fin. Eight

Fig. 135.



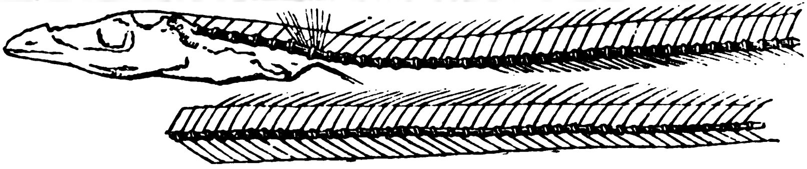


Fig. 136.

Fig. 135. *Anenchelum glaronense*, anterior part.
Fig. 136. A young specimen; the hinder end and caudal fin are wanting.

species are known from Matt, of which *Anenchelum glaronense** (figs. 135 and 136), the slenderest form, attained a length of 8½ feet. *Anenchelum latum*, Ag., which had a very large mouth with sharp teeth, was still larger. This genus, like the following one, is confined to Matt; but it is very nearly allied to the *Lepidopus argyreus* (or scabbard-fish), which is met with in the Mediterranean and along the African coast to the Cape of Good Hope. The only important differences consist in the smaller number of the little teeth and in the larger size and longer rays of the ventral fins, which, in the *Lepidopus*, are very small and like scales. The *Lepidopus* is remarkable for its brilliancy; it forms a long silvery ribbon, which works its way through the water with astonishing rapidity by its graceful undulations. Its mode of life and spawning-places are unfortunately unknown; but in April and May it approaches the coast, singly and not in shoals, and, according to Cuvier, it lives usually at a moderate depth in the sea.

The *Palæorhyncha* (fig. 137) are still more remarkable than the *Anenchela*. They have the same elongated ribbon-like body; but the toothless jaws are in them produced into a pointed beak, which gives these fishes a peculiar appearance. They remind us of the swordfishes—which belong to this family, but have not the same slender ribbon-like body. As in the *Anenchelum* and *Lepidotus*, the *Palæorhynchum* has a bony ridge along the dorsal and ventral margins; but the ossicles forming it stand in pairs, and from them two divergent branches are given off towards the interior. The most abundant and slenderest species is the *Palæorhynchum glaronense*, of which, in fig. 137, Prof. Heer has represented, half the natural size, a fine specimen lately found at Matt. The skeleton is almost perfect, but is broken in the middle, and is doubled up so that the head lies

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* Blainville, who first described this species, called it *Anenchelum glarisianum*; and Agassiz, following his example, has employed that name in three other genera. But the inhabitants of Glaris are "Glarner" and not "Glariser," and the fishes of that Canton are not "Glariser" but "Glarner-Fische" (*Glaronenses*). We must therefore correct the names given by Blainville and Agassiz. The word "glaronensis" is already more than 700 years old; it occurs in the most ancient document relating to Glaris, dated in 1029, and we find "Villicus glaronensis" in a document of 1128.

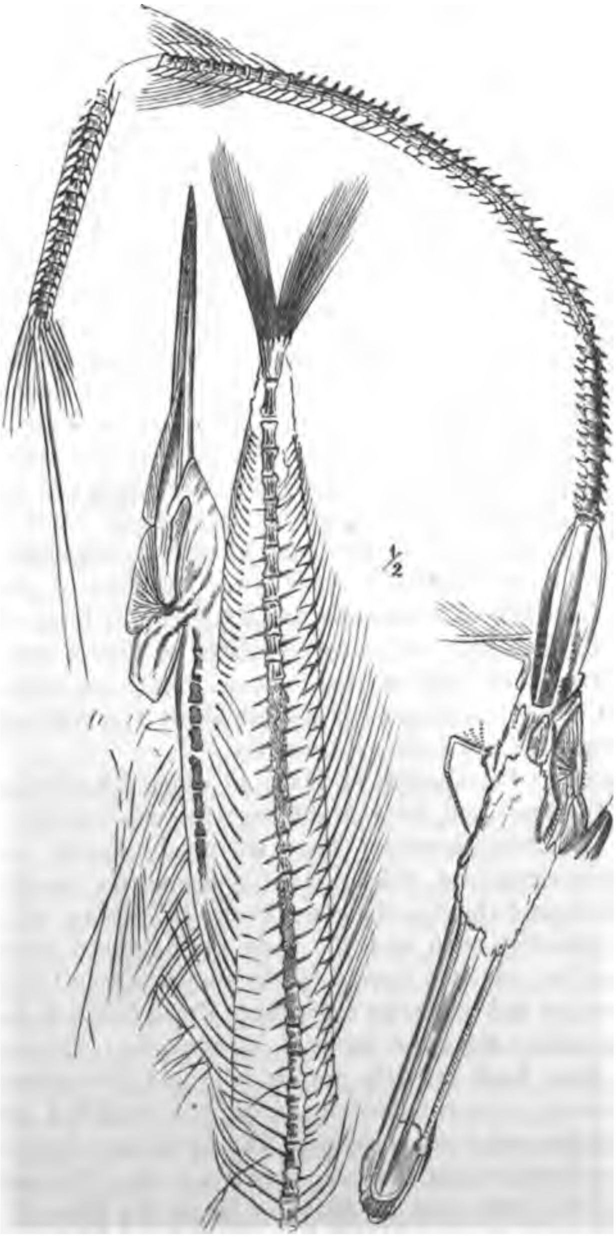


Fig. 137. Fig. 138.

Fig. 137. *Palæorhynchum glāronense.* Fig. 138. *Fistularia Kœnigii,* Ag.

near the tail. The largest species is *P. longirostre*, Ag., which reaches a length of 3 feet; its beak measures 8 inches, and is very finely pointed at the end; it is attached to a head about 2 inches long. *P. Egertoni*, Ag., and *P. medium*, Ag., are very similar; but the former has a shorter beak, and the latter, which attains a length of about 2 feet, is distinguished by having the rays of the dorsal fin 5 inches long. The broadest species is *Palæorhynchum latum*, Ag.

Anenchelum and *Palæorhynchum* are the two most important genera at Matt. Nearly allied to them are the two genera *Thyrsitocephalus* and *Nemopteryx*. In the latter (*N. crassus*, Ag.) the wide mouth is armed with large curved teeth, as in *Anenchelum*; but the body is of a stouter form, and the middle rays of the dorsal fin are forked. The pectoral fins are formed of very long fine rays; the caudal fin is rounded, and its rays are inserted upon the last six or seven vertebræ.

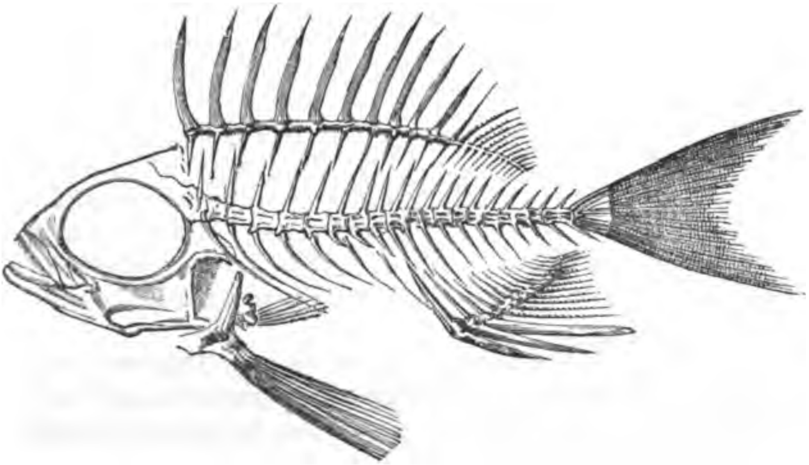
In *Thyrsitocephalus* we find a deeply cleft mouth armed with teeth and a very prominent lower jaw. The form of the body differs from that of *Anenchelum* and *Lepidopus* in being shorter and not ribbon-like, and it comes nearer to that of the genus *Thyrsites*, which inhabits tropical seas. Only one species (*T. alpinus*, v. Rath) is known; it is a fish about 8 inches long, with a pointed head and a strong dorsal fin.

The other Scomberidæ of Matt, to which *Thyrsitocephalus* forms the transition, are very different in form from the *Anenchela* and *Palæorhyncha*. They are much shorter, and are oval or elongate-oval, with a projecting snout and a small mouth. Among them we have:—the genus *Vomer* (*V. priscus*, Ag.), with small spherical teeth and the body much arched above the pectoral fins, which is represented by similar species in the seas of the warm and temperate zones (from Brazil to North America and in India); the genus *Isurus* (*I. macrurus*, Ag.), characterized by its large head and very narrow tail; and *Palimphyes* (with five species), a genus related to *Lichia*, but which had stronger pectoral fins and more vertebræ. The *Lichiæ* are characterized by their movable dorsal spines; they live in the Mediterranean and off the west coast of Africa as far as the Cape of Good Hope.

The Percoidei (or Perches) form a second family of the

Acanthopterygii, which, like the Scomberidæ, first appear in the Cretaceous deposits. They were represented at Matt by three genera, *Acanus*, *Podocys*, and *Pachygaster*, which are extinct and peculiar to the slate-quarries of Glaris. The genus *Acanus* includes six species (see *A. oblongus*, fig. 139). These are laterally compressed fishes, with a small obliquely cleft mouth and the jaws armed with brush-like teeth. Along the back runs a continuous dorsal fin, in the fore part of which the spines are very prominent. The genus *Beryx*, which now lives chiefly in tropical and subtropical seas, includes the most forms similar to living ones. These are beautiful fishes, clothed with silvery, rose-coloured, and purple scales, and possessing enormous opaline eyes and an individual dorsal fin. The Alfonsin (*Beryx splendens*) appear in March and April in great numbers on the shores of Madeira; they probably live in the deep water, and only approach the coasts in the spring.

Fig. 139.



Acanus oblongus, Ag.

Podocys minutus, Ag., is a small oval fish with long fins; and the *Pachygastres* are characterized by their large bellies, the line of which from the head curves out like a bow.

The most singular form of the Acanthopterygii is undoubtedly presented by the Aulostomidæ, to which belongs the curious pipefish (*Fistularia Kœnigii*, Ag., fig. 138). In this, the head is elongated into a tube which occupies as much as one third of the total length, and forms a sort of trunk, at the end of which the mouth is placed. The species from Matt sometimes attained a length of 3 feet, and had a thin and probably cylindrical body. The existing species are of equal size. Two of them inhabit tropical America; and a third is found in the Pacific as far as Japan; in fact all the species of this family are confined to the tropical and subtropical zones.

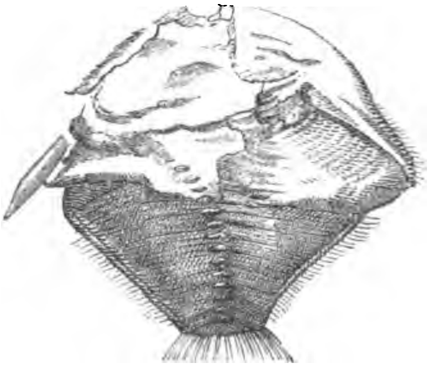
The Gadidæ (Codfish) are very rare at Matt. Only two species of Gadidæ have been discovered, one of which (*Palæogadus Troschelii*, Von Rath) is very like the common cod, which occurs in such incalculable abundance in our northern and temperate seas. On the banks of Newfoundland the codfish lives at a depth of about 300 feet, and generally lies close to the bottom; indeed the species of this family usually inhabit the deep marine zone.

Of the Salmonidæ we find the genus *Osmerus* (*O. glaronensis*), which is characterized by its double row of curved conical teeth and its forked caudal fin; the species may be compared to the common smelt (*Osmerus Artedi*, Cuv.), which is captured in abundance in the mouths of European rivers.

Of the Clupeidæ (Herrings, &c.) three species have been distinguished, the best-known of which (*Clupea brevis*, Ag.) is a small rather slender fish. At the present day the Clupeidæ are distributed through all seas, and they appear from time to time, as is well known, in such innumerable shoals that their capture furnishes one of the chief occupations of inhabitants of the sea-coast. These fishes probably live in the deeper parts of the sea, and ascend into the upper regions and approach the shore at their spawning-time.

The fishes just described are of forms which still occur abundantly in European seas; but the Loricata inhabit chiefly the tropical and subtropical zones, and their extreme limit is the Mediterranean. Matt has furnished five species, belonging to two extinct genera which are peculiar to that locality. One of these (*Acanthoderma*, Ag.) is very like *Balistes*; the other (*Acanthopleurus*) very nearly approaches *Triacanthus*, with which genus it ought perhaps to be united. Of *Acanthoderma* a fine recently discovered species is represented in fig. 140. Without

Fig. 140.



Acanthoderma orbiculatum, Heer. Half nat. size.
From the Museum of the Canton of Glaris.

the caudal fin this fish is rather more than 2 inches long; it is 2 inches 3 lines in height, and consequently nearly circular, whilst the other two species (*A. spinosum*, Ag., and *A. ovale*, Ag.) are longer than they are high. It is disciform, obtusely rounded in front, but somewhat narrowed towards the tail, although the base of the caudal fin is very broad. The nape is furnished with a stout spine, which the fish could probably erect or lay down upon its back at pleasure. Along the dorsal and ventral edges there are narrow fins formed by very delicate rays. The spinal column consists of short broad vertebræ, from which very thin indistinct ribs are given off. The fish was clothed with a leathery skin, which was very thickly set with spinous tubercles regularly arranged. In the general form of the body, in the structure of the small mouth, and in the nature of the tough warty skin, this genus agreed with *Balistes*, and must be regarded as its forerunner. The filefishes (*Balistes*) occur in the Mediterranean and in the Indo-Pacific Ocean in the middle and shallow-water zones; but in the latter they are said to live also in the abyssal zone. *Acanthopleurus*, which is very nearly allied to *Acanthoderma*, has, besides a spine at the nape of the neck, a pectoral spine resembling that of the *Triacanthus*, a genus only found in tropical seas. Two species have been discovered at Matt, namely *Acanthopleurus serratus*, Ag., and *A. brevis*, Eg.

Prof. Heer adds to this list a very large fish discovered at Matt a few years ago, and preserved in the collection of the Canton of Glaris. Unfortunately its head and tail are wanting, and its determination is consequently difficult; but the preserved portion of the spinal column is of considerable length, and the species was probably as large as the tunny. A pectoral or ventral fin 7 inches long and 1⅘ inch broad, which must have been derived from a very large animal, perhaps belonged to this fish.

The two Chelonians found at Matt were true sea-turtles, belonging to the same genus a species of which furnishes the highly prized tortoise-shell. We have represented the latter reduced in size (fig. 142) for comparison with the species from

Fig. 141.

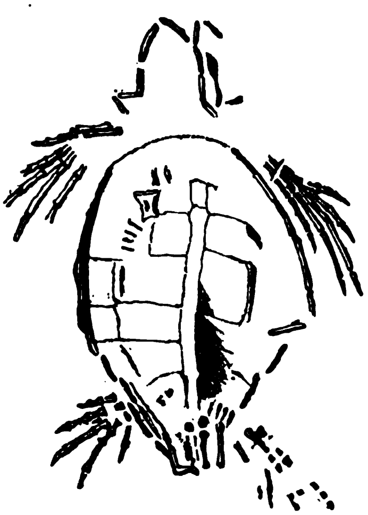


Fig. 142.

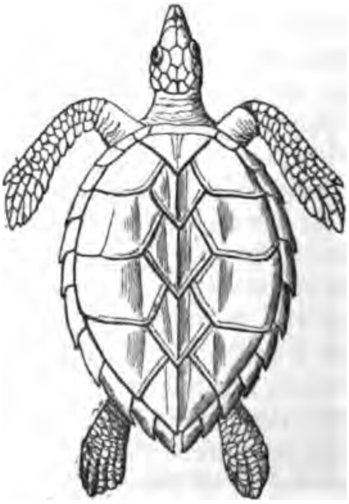


Fig. 141. *Chelonia ovata*, from Matt. One third nat. size.
Fig. 142. *Chelonia imbricata* (Hawk's-bill Turtle).

Matt (*Chelonia ovata*, Heer, fig. 141), which is much crushed, although its outlines, and in part also the ventral plates and phalanges, are easily recognizable. The oval carapace, which was narrowed behind, was very probably 4 inches 2 lines long and 2 inches 9½ lines broad. The marginal plates do not terminate behind in projecting points as in the living species, but they are blunt, so that where two of them are in contact there is a slight notch. The right side is a little displaced and broken behind; and the anterior margin is wanting. The median ventral fold is broader than in the existing species; and the five recognizable ventral plates have their edges much straighter. Of the head there are only indistinct traces—on the left side, apparently, the margin of the beak-like upper jaw, and on the right the margin of the lower jaw. The fore feet are much longer than the hind ones; we see in them five long toes with slender joints; but the scaly skin which covers these toes in the living species has disappeared. The fossil species is much smaller than the living one; for a living specimen attains a length of 5 feet, a breadth of 3 feet, and weighs several hundredweight. This species occurs chiefly in the torrid and warm zones, and only occasionally visits the seas of temperate climates. It lives on grasswrack and marine mollusca, and approaches the shore only to deposit its eggs.

The second turtle from Matt (*Chelonia Knorri*, Gray, Myr.) is still smaller than the *Chelonia ovata*; its carapace is only 2 inches 3½ lines long and 2 inches 6 lines broad, and is not narrowed behind, so that it is distinguished by its comparatively broader and more rounded carapace.

The two Birds of Matt are very imperfectly preserved, but they are of great interest as being the oldest known birds of Switzerland. One of them (*Protornis Blumeri*, Heer*), which Prof. Heer discovered at Matt a few years ago, is represented in fig. 143. The plumage is entirely wanting, and the bones are separated; but we can recognize the four-toed foot of a bird (*f*) with its thin tarsus (*e*) and tibia (*d*), the bones of the wings (*b*, *c*), and in front of these probably the lower mandible (*a*). The two wings lie close together; and in each of them we see the two strong bones of the forearm (1 inch 2$\frac{3}{10}$ lines long) and the bones of the metacarpus. The tibia is very thin, and 8½ lines long; the tarsus is only 6⅕ lines in length, and to it the toes, about 5½ lines in length, are attached, three of them being very nearly equal in length, whilst the fourth is a little shorter.

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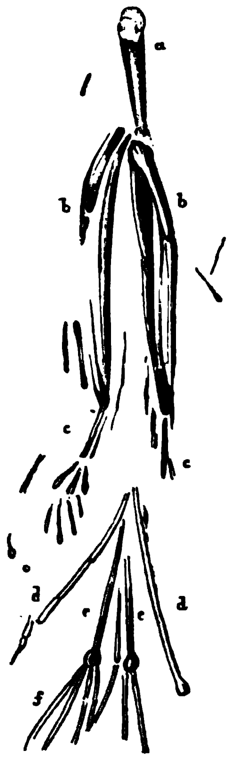
* Professor Heer has dedicated this species to the memory of Judge Blumer, of Glaris, who possessed a natural-history collection, which was, after his death, presented to the secondary school. To him Prof. Heer was indebted for the first book on natural history which the Professor ever saw.

Fig. 143.



Protornis Blumeri, Heer.

a. Beak?
b, *c.* Wing-bones.
d. Tibia.
e. Tarsi.
f. Toes.

The second species (***Protornis glaronensis***, Myr.) is very like the preceding, but smaller, and it had considerably shorter wings, toes, and tibiæ, whilst the tarsus was of nearly the same length. One toe is much smaller than the rest, and is directed backward. These birds were about the size of a lark, and appear to belong to the finch family.

If we now pass in review the fauna preserved in the slates of Matt, we find in it only two terrestrial animals, namely the two birds just referred to, whilst all the rest are marine. The turtles are saltwater species, rarely visiting the shores, although they did not live at the sea-bottom. Of the fishes the smelt or trout probably frequented the higher zones of the water, and perhaps only came accidentally from the estuaries into this region, as it is very rare; and the Acanthopleuri and Acanthoderma, like the existing *Balistes*, were also probably inhabitants of the upper marine zones; but all the other fishes, so far as they can be compared with existing species, chiefly lived at great depths and only occasionally visited the surface. Consequently the fish-fauna of Matt shows a predominant deep-sea character. There was also a proximity to the land, which agrees with the mode of life of many of the analogous living species dwelling in deep waters, yet still in the vicinity of land, such as the codfish, and probably also the herrings, the species of *Beryx,* and the ribbonfish.

The fauna of Matt affords evidence of a warm climate. Some species of fishes, such as the herrings, the smelts, and the codfish, correspond to species which now live in temperate zones; but the majority of the analogous species to *Lepidopus, Calistes, Xiphia,* and *Lichia* are not met with either in the north or in the Mediterranean sea; they belong to a warmer zone, and move southwards towards the tropics. With them are some forms which are now limited to the tropical or subtropical seas, such as the pipefish and the species of *Triacanthus* and *Thyrsites.* The turtles also give the fauna a southern character, whilst the birds seem to belong to a group which is now spread over all zones.

A few fish-remains occur in the slate-quarries of Attinghausen, in the Canton of Uri, which is the only locality, with the exception of Matt, where they have been hitherto found in Switzerland. They belong to four species, among which the genera *Anenchelum* and *Palimphyes* may be recognized.

If we examine places in other countries where there are deposits with fossils, we do not find any species with a well-determined geological age which are identical with any of the species from Matt*. The fauna of Matt is consequently as yet unique.

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* At the southern foot of the Hochberg, near Traunstein, a *Palæorhynchum gigas* has been discovered in a strongly micaceous sandstone, the stratigraphical relations of which, however, are difficult to make out. According to Emmerich, this rock belongs to the oldest Eocene (see Zeitschr. der deutsch. geolog. Gesellsch. 1860, p. 375). In a marine formation in Alsace a *Palæorhynchum latum* has been found, together with *Amphisyle Heinichii,* Heck., *Meletta crenata,* Heck.?, *Lamna contortidens,* Ag., *Oxyrhina hastalis,* Ag., and leaves of *Eucalyptus oceanica, Sabal oxyrachis, Zonarites multifidus,* Brong., sp., and *Ceramites Kœchlini,* Heer (see Delbos and Kœchlin-Schlumberger, 'Description géologique du Département du Haut-Rhin,' ii. pp. 69 and 512, and Sitzungsber. der Wiener Akad. 1862, p. 492). According to these organic

The turtles, indeed, resemble two English species, one of which (*Chelonia Benstedi*, Owen) is found in the Chalk of Kent, and the other (*C. obovata*, Owen) in the Purbeck limestone; but the Matt turtles differ in several respects both from these and from the species in the Tertiary formation. The fishes are very different from those of the Jurassic period; but by the herrings they approach the fishes of the Cretaceous, although they differ from the Cretaceous fishes not only in species but also in most of the genera. Even the marine fishes of the most recent Cretaceous beds of Westphalia (Baumberg and Sendenhorst) differ from the Swiss specimens both generically and specifically. The Swiss fishes are most nearly allied to the fishes of Monte Bolca, a celebrated locality in the neighbourhood of Verona, where, among the fishes, are the curious sea-snipes, *Fistularia*, and the herrings. Here also the Scomberoids are numerous (28 species); and, although *Palæorhynchum* and *Anenchelum* are absent, the genus *Xiphopterus*, Ag., is very nearly allied to the latter. Agassiz enumerated 127 species of fish from Monte Bolca*, and referred them to 77 genera, 39 of which still exist, whilst 38 are extinct. Here, therefore, only half the genera are extinct, whilst in Matt nearly four fifths of the better-known genera have ceased to exist. We must, however, take into consideration that 8 of the extinct genera at Matt are very like some living genera, and that several others may have been too artificially separated. It is certain that the fish-fauna of Matt differs considerably from that of Monte Bolca, and contains a greater number of types which do not occur at the present day. The entire absence of identical species may be in part due to the circumstance that these faunas belong to two separate seas—that of Monte Bolca to the sea which then covered the whole

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remains, the Alsatian fish-beds would seem to belong to the Tongrian. Perhaps the slates of Matt ought also to be referred to this formation, which, according to different authors, belongs either to the upper part of the Eocene or to the Lower Miocene.

* See Agassiz, 'Recherches sur les Poissons fossiles,' iv. p. 37. Subsequent investigations have added some new genera, and shown that two (*Gastronemus* and *Pterygocephalus*) which were supposed to be extinct are still living; but the proportion is not essentially altered by this recent discovery.

of what is now the plain of the Po, and was connected with the Mediterranean, and that of Matt to a comparatively narrow arm of the sea which traversed Central Europe. Then, at Matt, we have the fish-fauna of the deep sea, whereas at Monte Bolca we find rather the inhabitants of the coast and of the upper zones. Swordfishes resembling the *Palæorhynchum* of Matt have been found in the Calcaire grossier of Paris and in the Isle of Sheppey*, and a similar but much more scanty fauna occurs in some Tertiary deposits of Galicia and Moravia, and near Ofen. Here we find, together with herrings, the genus *Lepidopides*, Heck., which is very nearly allied to *Anenchelum*. The deposits of Monte Bolca belong, like these, to the Tertiary epoch, which immediately follows the Cretaceous. The fossils of Matt, therefore, render it probable that the slates of that place were deposited during the Tertiary period; but the greater number of extinct genera in them leads Prof. Heer to suppose that they belong to an earlier stage of the lower Tertiary rocks than the deposits of the Monte Bolca.

Unfortunately, the stratification which might have aided us in determining the age of these slates is so confused at Matt that no conclusion can be drawn from it. The slate-quarries on both sides of the valley are surrounded by blackish-grey or yellowish fine-grained sandstones; and on the planes of their stratification we often see silvery spangles of mica. These sandstones are very thick in some places, but they contain no fossils. The whole valley-bottom from Engi to the extremity of the Sernfthal consists of these sandstones and of dark slate rocks; and even the mountains enclosing the valley are formed of the same sandstones up to a considerable height. Here and there the sandstone is converted into a dark green mass, with lighter green or greenish-grey roundish spots, and scattered white points produced by felspar and laumonite. These green sandstones speckled with white are known as Tavigliana sandstones*, because they are very finely developed on the Alpe Tavigliana (Taveillanaz) at the Diablerets. In the Fuhrbachtobel, in the Canton of Glaris, these green sandstones are 500 feet thick, and form regular beds which alternate with shining black slates. The same sandstones also occur at the bottom of the wild valley of Durnach and at the Hausstock. This rock most nearly resembles the trap rocks of Vicenza, and, like these, probably owes its origin to submarine volcanic eruptions. As dry land separated the Swiss sea from that of Upper Italy, these deposits cannot have been conveyed from Italy, but probably rose out of the bosom of the earth in the place where they are now found. From the locality of eruption the volcanic substances would be spread about in various directions; and it is thus easy to understand how they alternate here and there with marine deposits, or even pass into or become amalgamated with them.

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* The Eocene fishes of the Isle of Sheppey have not yet been studied with the necessary care. The swordfishes (*Cœlorhynchus* and *Tetrapterus*) which occur there constitute an approximation to the fauna of Matt, as does also the genus *Hemirhynchus*, Ag., peculiar to the Parisian Calcaire grossier, which is so near the *Palæorhynchum* that it is only distinguished from it by the lower jaws, which are a little shorter in the *Hemirhynchus*.

The limestones which occur here and there with the slates and sandstones are of great interest. They are dark grey, and split into thin laminæ, the surface of which usually acquires a light grey colour by the action of the air. In some places they contain great quantities of seaweeds (*Fuci*), and are on that account called Fucoidal Shales. They are found in the valley of the Sernf, at the Panix Pass near Seeli, on the Ramin Alp to the east of Elm, on the Tschingelalp (in the sides of the rocks), and to the north of Martinsloch.

In the slate-quarries of Matt, however, and their immediate neighbourhood no marine plants have as yet been found; so that the relations between the fauna of Matt and this marine fauna cannot be ascertained.

Rocks which have been associated together under the name of *Flysch*† are tò be found sometimes penetrating far into the mountains along the whole northern border of the Swiss Alps, from Savoy to the Vorarlberg, and in the Bavarian Alps; and everywhere the Flysch has the same character as in the valley of the Sernf. Everywhere the Flysch mountains present softer outlines than the limestone mountains; their summits and crests are not so sharp and angular; and their slopes and terraces are richly carpeted with flowering plants, but exposed to the ravages of torrents. The Flysch rocks form in general a rather narrow band following the line of the Cretaceous zone. They surround the limestone chain of the Moléson, and occupy a broad belt from the Ormonts to the Lake of Thun, where they attain their greatest thickness and extension. From Sepey to Mühlenen, on the Kander, for a length of 11 Swiss leagues, a breadth of 3 Swiss leagues, the Flysch rocks extend, and here and there attain a thickness of 5000 feet. The Niesen chain is entirely composed of them. From the Lake of Thun along the Ralligstock to Sarnen in Unterwald we may follow a band of these rocks, which is broadest in Obwald. It loses itself at the Lake of the Four Cantons, but reappears in the Canton of Schweiz, and continues through the valleys of the Sihl and the Wäggi towards the northern boundary of the Canton of Glaris and the Lake of Wallenstadt. There it divides into two arms, which surround the chain of the Sentis: the northern arm is very narrow, and constitutes the boundary between the limestone and the Miocene; but the southern arm goes from the vicinity of the Leistkamm to the Vorarlberg, passing by St. Johann, Wildhaus, and the lower valley of the Rhine. Like the Cretaceous formation, the Flysch penetrates the Alps in the district of the Upper Rhine. Almost the whole of the Prättigau belongs to these rocks; and the fertile fields, rich in fruits and vines, on the road from Mayenfeld to Coire, rest upon the Flysch. The deep ravine which leads frem Ragatz to the baths of Pfäffers shows very beautifully the dark Flysch rocks with their steep broken sides, the base of which is worn away and often undermined by the waters. We also find Flysch rocks with the same

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* Some remains of plants have lately been discovered in the Tavigliana sandstones at the Dallenfluh, near Sigriswyl; but they are so badly preserved that they cannot be exactly determined. They are the remains of land plants, among which may be distinguished an *Equisetum* (horsetail) and some twigs of Conifers, which seem to have belonged to *Sequoia Sternbergi*.

† Flysch, or Flys (derived from *fliessen*, *flinsen*, to flow) is the name given in the Simmenthal to sandy marl shales which are easily weathered, and which contain fucoids (*Chondrites intricatus*). This name has been applied

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by Studer to all similar rocks belonging to various formations, while Escher de la Linth applies it only to those rocks overlying the Nummulitic formation.

character in the valley of the Weisstannen, and can trace them thence back to the valley of the Sernf, where we first met with them. By the Freiberg the Flysch goes into the valley of the Linth, and is continued over the Klausen into the valley of the Schächen, and as far as Altdorf in the Canton of Uri.

The Flysch consequently holds an important place among the rocks of Switzerland. It takes a considerable position in the Alpine country, as well as in several valleys; it raises itself to inaccessible summits of mountains, and often attains an apparent thickness of 2000 metres. Throughout the whole of this district, wherever the Flysch is met with, it is composed of the same kind of rocks—blackish-grey, readily disintegrated shales, dark fine-grained sandstones sprinkled with small plates of mica as if with silver, with here and there light green tufaceous Tavigliana sandstones and fucoidal shales. Whilst the Tavigliana sandstones are probably of volcanic origin, the shales, sandstones, and limestones were all undoubtedly produced by deposition in water. The sandstone, which is generally fine-grained, becomes converted here and there into a conglomerate containing pebbles from the size of a walnut to that of a man's fist (as at Saane, near Moulins); and these sometimes contain fossils belonging to older formations (as on the Dent du Midi, at the Molire, and at the Voirons)*. Probably the localities where the sandstone acquires this form were places at which rivers or brooks flowed into the sea, carrying with them rolled pebbles.

In some parts of Switzerland enormously large granite blocks occur in the Flysch; and their origin is still a mystery. We find such blocks among the Flysch sandstones near Sepey in the Canton of Vaud, in the valley of the Habkeren, in the Bernese Oberland, and at the head of the valley of the Sihl. Near Sepey the blocks consist of gneiss, protogine, and talc, and alternate in thick beds with the Flysch: in the valley of the Habkeren the blocks of granite are very large; one of them is estimated by Prof. Studer to contain 500 cubic feet. Their angles are rounded off; and, indeed, many of them are almost spherical. At the Traubach and the ditch of Lambach, on the north slope of the Bohleck, they are fixed in the Flysch; but at the bottom and on the flanks of the valley of the Habkeren they are laid bare, and might therefore easily be taken for erratics but for their being rounded and composed of a granite foreign to the Swiss Alps. At Yberg, in the valley of the Sihl, side by side with the blocks of granite, occur large blocks of Lias and Brown Jura, which have accumulated in great masses cemented together by Flysch; so that one might imagine them to be part of the mountain, if the difference of the rock and the abundance of the fossil remains contained in it did not contradict such an assumption. The Flysch is seen also in the parish of Grabs, where granites foreign to the Alps and gabbro are mixed with Liassic, Oolitic, and Oxfordian rocks.

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* The Belemnites which have been found in the Flysch of Sepey and of the Gurnigel are probably to be explained in the same way. The hard Belemnites, which readily become detached from the rock, might easily be washed out and carried down to more recent formations.

In other countries these foreign blocks have been observed in the Flysch, as at Bolgen in Bavaria, and at the northern base of the Apennines in Northern Italy. Mineralogically these granites are analogous to those found in the valley of Habkeren; none of them occur in the neighbouring mountains; and their origin is still unknown. We shall see, in a later part of this work, that there was a period when Switzerland was strewed with numerous rocky fragments from the Alps, and that their transport into the lowlands may be satisfactorily explained by the action of glaciers. But this mode of transport cannot be applied to the granite blocks of the Flysch.

No fossils occur in the Flysch rocks, except in the slates of Matt and in the fucoidal shales; and we might therefore assume that all life had been extinguished in this region at that epoch; but if this had really taken place, and the land had been completely covered with ice, this phenomenon must have been also manifested in other localities, for which there is no evidence. On the contrary, the organic remains belonging to the Eocene period, we know, from other places, decidedly indicate a warmer climate than that which now prevails in these latitudes. The scantiness or almost entire absence of organic remains in the Flysch formations is one of the most singular and inexplicable phenomena in the geological history of Switzerland, and renders it difficult to decide the age of the Flysch rocks themselves. The fish-fauna of Matt is of great significance; it tells us that these slates are younger than the Jurassic and Lower Cretaceous rocks, but gives us no decided answer to the question whether they belong to the Upper Cretaceous or the Eocene series, although the latter seems most probable. The same doubt exists with respect to the seaweeds of the fucoidal shales, as will appear from a closer examination of them.

The localities for these marine plants are scattered over nearly the whole Flysch regions of Switzerland* and of neighbouring countries. The seaweeds generally occur in considerable quantities, and not unfrequently fill whole beds of rock. They are all delicately formed plants, most of which when alive were probably of a red colour; but now they merely show a black trace on the rock, and a complicated network of lines and bands. High up in the Alps, perhaps 7000 or 8000 feet above the sea-level, slabs of rock are met with covered with the impressions of plants whose nearest relatives, at the present day, are only found on the sea-shore.

Some of the most important forms of Flysch marine plants are shown in Plate X. At present we know altogether thirty species, which are referred to nine genera. The principal genus is *Chondrites*, with which we are already acquainted (see pp. 59, 69, 143); this not only contains the greatest number of species, but it predominates by its prodigious multiplication. The most abundant are *Chondrites intricatus*, Brong., sp., and *Ch. Targi-*

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* Prof. A. Escher de la Linth collected from all parts of the Swiss Alps a great number of the Flysch marine plants, which Prof. Heer has carefully studied. They are from Leysin above Aigle, the Rouvines and Sepey in the Canton of Vaud, from Mühlenen at the Niesen, the valley of Habkeren, the Bohleck and Weissenburg in the Canton of Berne, from the valley of Wäggi, the Hakenpass, the neighbourhood of Einsiedlen, and Yberg, from the Teufenbachtobel above Gersau, from Simitobel near Wildhaus, from the Wänden near Elm, the pass near the Martinsloch, the Panixerpass near Seeli, the Walenbütz Alp and Foo, the Trinserfurkeli between the Ringelkopf and Sardonen, the Laaseralp on the Grey Horns, the Rhätikon and Conters in the Prättigau, Peist and Fandey in the Schalfick, from Blanken above Balzers, the Luziensteig, from Falknis, and from the Fähnern in the Canton of Appenzell. The species preserved in the Museum at Berne have been studied by M. F. de Fischer-Ooster (see his memoir 'Ueber die fossilen Fucoiden der Schweizer-Alpen,' Berne, 1858).

onii, Brong., sp., which present numerous forms*. The ramifications, which are all of equal width, diverge at acute angles, are of very unequal length, and frequently ramified; they are sometimes collected into separate tufts. In *Chondrites patulus*, Fisch.-Oost. (of which Plate X. fig. 5 represents a specimen from the pass of Panix), the branches are simpler, and diverge nearly at right angles. *Chondrites affinis*, Sternb., sp., and *C. inclinatus*, Sternb., sp., are much larger, and sometimes spread over whole slabs; of the latter, Pl. X. fig. 7 represents a fragment from the Trinserfurkeli. The genus *Munsteria* includes large seaweeds characterized by numerous transverse striæ, sometimes oblique but generally almost annular, and by fine points which lie between the striæ. The *Munsteria annulata*, Schf., from the Fähnern, is shown in Pl. X. fig. 8. These Algæ probably formed cylindrical ringed tubes of firm leathery consistence. In *Halymenites* we find similar numerous dots scattered over the frond, and probably due to the presence of small masses of spores; but the transverse striæ are wanting. The *Halymenitæ* are generally large plants, in some of which the stems are much branched (as in *H. flexuosus*, Fisch.-Oost.), whilst in others they are simple and cylindrical (*H. lumbricoides*, Heer, Pl. X. fig. 11, from the Fähnern); others, again, are enlarged here and there into a club-like form: these last are less like the *Halymenia* than the living genus *Encœlium*, in which we find a tubular frond sprinkled over with small sporangia.

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* *Chondrites intricatus*, Brong. (Pl. X. fig. 1 from Gersau, fig. 2 from Martinsloch), forms tufts spreading in all directions, the frond branching from the base. The ramifications are from ¼ to ½ millimetre in breadth. *Ch. intricatus Fischeri*, Heer (*Ch. æqualis*, Fisch. not Brong., Pl. X. fig. 4, from Blanken above Balzers) is rather larger, with longer, broader, and more divergent branches. In *Chondrites Targionii*, Brong., the mode of ramification is the same, but the branches are considerably broader and longer (½–1½ millimetre in breadth), and the whole plant is stouter and larger: the larger form, however, which constitutes the true *Ch. Targionii*, Brong. (with the branches 1–1½ millimetre broad), is rare in Switzerland; but the smaller one, with branches ½–1 millimetre in breadth, which Fischer-Ooster has distinguished as *Chondrites arbuscula* (Pl. X. fig. 6, from the Fähnern), is very abundant, and, indeed, is the commonest seaweed of the Swiss Flysch. The form with outspread branches has been distinguished as *Chondrites Targionii expansus* (Pl. X. fig. 3, from the sides of the rocks on the Tschingelalp).

The genus *Caulerpites* (*C. filiformis*, Sternb., Pl. X. fig. 9), which is not uncommon on the Fähnern, is a delicate little plant densely covered with small leaflets. Two species of *Zoophycos* (*Z. brianteus*, Vill., sp., and *Z. flabelliformis*, Fisch.-Oost.) from Gurnigel, plants of considerable size, are very like those of the Brown Jura (see pp. 141, 142), and possessed large leaves arranged in whorls or in very close spirals. The *Palæodictyon singulare*, Heer (Pl. X. fig. 10, from Falknis*), differs greatly from all the preceding plants; it forms a net-like frond with its branches so curved as to produce nearly complete roundish meshes. In its reticulation it reminds Prof. Heer of the *Halodictyon cancellatum* (Bory, sp.) of the seas of warm climates, and which has much more irregular meshes.

That smaller Algæ grew upon the larger ones, as is so frequently observed now among seaweeds, is shown by the specimen from Gersau represented in Pl. X. fig. 1, in which a growth of *Chondrites intricatus* has settled upon the *Halymenites minor*. But it is remarkable that no Hydroid Polyps or Polyzoa (e. g. *Escharæ*) seem to have attached themselves to the seaweeds, although this is commonly the case in existing seas.

If it is difficult to determine the nature of the *Palæodictyon*, this is the case in a still higher degree with the singular structures which may be called "wormstones" (*Helminthoidæ*). A part of one of these is shown in Pl. X. fig. 12. A raised spiral line first surrounds an oval space, but then turns outwards in a blunt loop and runs parallel to the preceding turn, but in the opposite direction, and then again bends outwards in the same way. In this manner are produced a number of parallel ribs united at the ends, with tolerably deep furrows between them. In perfect specimens the rib forms a continuous thread from its beginning to its end. The convolutions usually become gradually larger from the starting-point; or only a few of them are longer than the rest and generally more strongly curved. Frequently two or more systems of convolutions lie close together, without any contact or intermixture of the loops. Two species may be distinguished: the smaller one (*Helminthoida labyrinthica*, Heer, Pl. X. fig. 12) is the most abundant; the larger one (*H. crassa*, Schafth.) has convolutions three or four times as broad.

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* Professor Heer received this species of *Palæodictyon* from Weissenburg, and from Ghelindjik in the Crimea; a second much smaller species (*P. textum*, Heer), from the Falknis; a third (*P. scriptum*, Heer), in which light tortuous lines enclose irregular meshes, from Walenbütz, the Ormonts, and Gründel, in the upper valley of the Sihl; and a fourth very large species with closed meshes from the Walenbützalp.

These wormstones were probably formed by marine worms*. They remind us vividly of the galleries made by the bark-beetles and those made by many mining caterpillars. The passages left by the worms were afterwards filled up with a harder and more calcareous mass, which now forms the ribs in the slabs (and the furrows in the counterslabs).

The *Helminthoidæ* are distributed throughout the whole Flysch region, and are just as abundant in Upper Italy (*e. g.* Liguria) as in Switzerland. Hence, enigmatical as their nature may be, they are peculiar to the Flysch, and are much more readily distinguishable than the seaweeds of that formation. The latter are not remarkable for any variety or singularity of form; they are plants such as still exist in the seas of various zones, and such as did occur in earlier periods, as in the Triassic and Liassic seas. The fucoids present no great changes, at all events in external form, from the Triassic epoch to the present day. The species, no doubt, have changed; but those of different periods are sometimes so nearly allied as to have been frequently confounded with one another*; and they can only be employed with the greatest caution for the distinction and definition of formations, more especially as the most nearly allied living species vary greatly in size and form †, and the same forms appear in perfectly different genera ‡. But a careful comparison shows that the marine plants of the Flysch have the same general character throughout the whole of Europe; and the species occur similarly associated in Switzerland, Bavaria, Austria, Savoy, Upper Italy, and Sicily. Most of the genera of the Flysch (such as *Chondrites*, *Munsteria*, *Halymenites*, *Zonarites*, and *Caulerpites*) inhabited the Liassic and Jurassic seas; but the species, although sometimes nearly allied, were different, as may be seen by a comparison of the plants figured on Plates IV., IX., and X. Even with the Swiss Cretaceous formation, the Flysch has no species in common: the species of *Chondrites* found in the Neocomian (p. 198) are easy to distinguish from those of the limestone shales of the Flysch; and in the later Cretaceous stages of Switzerland no Algæ have yet been detected. They are, however, found in Upper Italy; and Prof. Heer has received numerous fucoids from Morosolo and the environs of Bardello and Biandrone near Varese, and also from Credano and Grumello del Monte in the province of Bergamo. They are in yellowish-white calcareous beds, which, according to Stoppani,

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* Very similar structures occur in the transition or Cambrian rocks of Llanpeter, in Wales. Sir Roderick Murchison, in his 'Silurian System, vol. ii., gives figures of them (plate 27) under the name of Myrianites and Nemertites. In vol. i. p. 363, under the head of the Cambrian rocks of Caermarthenshire, Sir R. Murchison mentions these convoluted remains discovered in the faces of the schistose building-stone of Llanpeter, and observes that, after a long examination, no zoologist had at that time ventured to pronounce that they ever belonged to the animal kingdom. Mr. W. M'Leay subsequently pronounced these convoluted forms to have been "sea-worms" (Silurian System, vol. ii. p. 699). Prof. Heer deems it more likely that these convoluted remains were the galleries of sea-worms than the worms themselves, as nothing is to be seen of the animal, and the convolutions are so regular that the Professor cannot imagine them to have been produced simply by the folding together of the worm. The great resemblance of the Myrianites and Nemertites of the Cambrian rocks to the *Helminthoidæ* of the Flysch renders it probable that these structures were produced by similar creatures, and justifies Professor Heer in his opinion that the same marine worms cannot have been wanting in the intervening geological formations.

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* The statements that the same species occur both in the Jura and in the Flysch are founded upon errors of this kind. *Chondrites furcatus*, Schafhäutl (Geogn. Unters. des süd-bayer. Alpengeb. pl. vi.), from the Lias, is quite distinct from *C. furcatus*, Brong., sp., from the Flysch; *C. Targionii*, Zigno (Flora Oolitica, pl. i. fig. 4), from the Jura, from *C. Targionii*, Brong.; and *C. intricatus*, Zigno, from the species which is so common in the Flysch. Few plants have been so much misunderstood and confused as *Chondrites Targionii* and *Chondrites intricatus*, Brong.

† E. g. *Chondrus crispus*, Linn., sp., *Plocamium coccineum*, Kg., *Gelidium corneum*, &c., which are distributed in all seas.

‡ Prof. Heer compares with the *Chondritæ* species of the genera *Chondrus*, *Chondria*, *Sphærococcus*, *Gigartina*, *Dictyota*, *Laurencia*, *Dieurella*, *Bostrychia*, and *Gelidium*. The *Gelidium fastigiatum*, Kg., from South Africa most nearly agrees with *Chondrites Targionii*, its frond being also ramified from the base, and each branch being very soon divided again. But this furcation is more regular than in *C. Targionii*, and the outermost ramifications are shorter and more uniform.

Desor, and Mortillet, belong to the upper Cretaceous series. They include *Chondrites intricatus*, *C. Targionii* in many forms, and *C. inclinatus*, species found in the Swiss Flysch. From this circumstance we might be tempted to refer the Swiss fucoidal shales to the upper Cretaceous period; and this view might be supported by the flora of the Algæ of the Eocene Monte Bolca, as in these marine plants the Flysch fucoids are wanting *, whilst large-leaved Florideæ, resembling the blood-red *Delesseriæ* of our existing seas, are very abundant. But, on the other hand, we find the fucoids of the Flysch in the Nummulitic formation, which is undoubtedly more recent than the Cretaceous, and belongs to the Tertiary epoch. In Switzerland there is only a single locality (Argentine, in the Canton of Vaud) where a Flysch species (*Halymenites flexuosus*, Fisch.-Oost.) and a peculiar *Zoophycos* have been found in the Nummulitic limestone; but Prof. Heer has obtained more Flysch specimens from Italy. Near Pistoja, in Tuscany, on the railway between Borgianico and Valdibrana, the Swiss Flysch fucoids (*C. intricatus* and *Targionii*) occur in a sandy marl with Nummulites (*N. Ramondi*, *Guettardi*, and *variolaria*) †. Escher de la Linth discovered these species more than thirty years ago at Randazzo in Sicily. According to Prof. Gemellaro, these deposits belong to the Nummulitic formation. The same fucoids (*C. intricatus*, *patulus*, *Targionii arbuscula*, and *affinis*) also occur in greater abundance in the yellowish-white limestones of Trasiano, near Reggio in the Modenese Apennines, which are regarded as lower Tertiary. And in the Nummulitic region of Biarritz, Prof. Heer's friend Dr. C. Gaudin has collected very well-preserved Flysch fucoids (*C. intricatus*, *Fischeri*, and *Targionii arbuscula*).

The *Caulerpites filiformis*, Sternb. (Plate X. fig. 9), furnishes an additional bond of union with the Tertiary flora; it is not uncommon on the Fähnern, and is also found in the "Calcaire grossier" of Carinthia; and a *Munsteria* which has been found in the Monte Pastello is in an undoubtedly Tertiary rock, and is scarcely distinct from *M. annulata* * (Pl. X. fig. 8).

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* The genera *Chondrites*, *Zonarites*, and *Caulerpites* are represented, but the species differ from those of the Flysch. A plant is found there very like the *Sargassites Studeri*, Fisch.-Oost. (Fucoid. pl. xiii. fig. 4), from the Fähnern, which specifically differs little from that at Monte Bolca, figured by Massolongo under the name of *Albucastrum perianthoideum* (Specimen Photographicum, pl. xxiii. fig. 1). It belongs as little to the *Sargassum* as to the Liliaceæ, and ought rather to be associated with the Acanthophora.

† See G. de Mortillet, 'Note sur le Crétacé et le Nummulitique des environs de Pistoia,' p. 3.

All this shows that the Swiss Flysch fucoids stand in a near relation to the Nummulitic formation of Switzerland, and that the rocks enclosing them were probably formed during the Eocene and not the Cretaceous period. If the deposits containing fucoids near Varese and in the province of Bergamo really belong to the Cretaceous epoch, we are compelled to assume that a number of species are common to the Upper Cretaceous and the older Tertiary periods. But it is very remarkable that of the nineteen fucoids which Dr. Debey has described from the upper Cretaceous of Aix-la-Chapelle, two species occur nearly allied to the *Chondrites intricatus*, but there is not a single species identical with any species from the Flysch †.

In the Flysch region the *Nummulitic formation* occurs, which is especially rich in fossils. The rocks of which it consists are filled in many places with circular shells having a lenticular transverse section, which have been compared to pieces of money, whence the name of Nummulites or money-stones. These shells belong to the same division as the Rhizopoda, to which we have already referred (see p. 201); but they are much larger than those of the older formations or of the present day, and at no time did these animals occupy so important a position or grow to so large a size as at the Nummulitic period. An abundant marine fauna is associated with these shells in the same rocks; and the constitution of the strata, their distribution in Switzerland, and their position with regard to the Flysch will now be considered.

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* Massolongo has described it as *Caulinites Catuli* (Atti dell' Istituto Veneto, iii.).

† One species (*Chondrites jugiformis*, Deb.) is very like *C. serpentinus*, Heer, from the Neocomian. Dr. von der Marck cites *C. intricatus* and *C. Targionii* from the uppermost Cretaceous beds of Westphalia ("Fossile Fische, Krebse und Pflanzen aus dem Plattenkalk der jüngsten Kreide Westphalens," Palæontographica, July 1863); but his figures do not at all reproduce those species.

The Nummulitic rocks consist of quartzose sandstones varying in colour from brownish yellow to blackish brown, of sandy shales, and partly also of grey or black limestones, the latter in some places so hard and compact as to be used for building-stones. The Nummulitic limestone of the Ralligstöcke (known as "Merligerstein") is employed for building houses in Berne, and the sandy coarse-grained limestone for paving the streets of that capital. In many places the Nummulitic formation contains thin beds of coal, which may be traced, although with many interruptions, from Savoy to the Lake of Thun. This coal here and there forms deposits as much as 6 feet thick, and it may be observed in strata on the right bank of the Arve in Savoy, to the south of Arrache and Pernant, at the end of the valley opening out at Bellegarde. There are thin beds of coal on the Diablerets, 9600 feet above the sea, as well as at the Beatenberg, 3400 feet above the sea, and at the Niederhorn, about 5700 feet above the sea. Here coal has been worked for a century, and it is employed in Berne for the manufacture of gas. Traces of the coal-deposit may also be found at the Hohgant and the Ralligstöcke. The coal is no doubt produced from plants; and its presence indicates the former existence either of peat-mosses or of a marshy shore fringing the Nummulitic sea. No recognizable remains of plants, however, have as yet been discovered in it; but numerous marine animals are discovered at all the places just mentioned; and at the Ralligstöcke, land and freshwater Mollusca occur, leaving no doubt that there was dry land in the neighbourhood.

Thus the Nummulitic formation extends from the valley of the Rhone to the Lake of Thun, almost everywhere following the Flysch. The Nummulitic sea probably, like the Flysch sea, formed a narrow strip along the northern border of the Alps, and penetrated here and there deeply into the region of the present Swiss Alpine mountains. The Nummulitic formation occurs in narrow bands on the Titlis, at the Jochpass and the Surenen, and on both sides of the valley of the Schächen in the Canton of Uri; in the Canton of Glaris it covers the Glariden and the Bifertengrat; and even the summit of the Tödi seems to belong to it. In the Gross- and Kleinthal it occupies the highest passes (the Kisten, 2760 metres above the sea-level, and the pass of Panix or Bündnerberg); and it may be traced into the valley of the Rhine. Like the Flysch, the Nummulitic formation approaches the Lake of Thun in a bed having a northerly direction, and is continued into the valley of the Rhine, and surrounds the Sentis. It is remarkable that, from the basin of the Rhone to the Lake of the Four Cantons, the Nummulitic rocks have the same character; but they then change from the Bürgenstock onwards, and remain constant as far as the Canton of Appenzell. This change, according to Studer, is due to the intermixture of green grains in the sandstone, and to the introduction of red ferruginous rocks, so that dark green or red colours often predominate throughout the formation. In Appenzell, however, the predominant colours vary from dark green to nearly black.

The Nummulitic rocks are closely related to the Flysch in their distribution; Studer and Escher de la Linth agreed that they lie beneath the Flysch, and therefore the Nummulitic strata must be older than the Flysch. These geologists particularly alluded to the fact that on the Fähnern in the Canton of Appenzell, and near Yberg in the Canton of Schwyz, the Flysch with its fucoids lies upon the Nummulitic limestone under conditions which preclude a reversal of this order of stratification.

In Bavaria also (in the side rocks of the Grünten*), and in Savoy (on the Voirons), the relative position of the strata lead to the same result. The Nummulitic strata and the Flysch are so intimately related that they probably belong to one great geological period, the *Eocene*, which follows immediately upon the Cretaceous, and forms the earliest division of the Tertiary formation.

Nummulitic Fossils.

Most of the fossil animals of the Nummulitic period were inhabitants of the sea. They show us that, after the Cretaceous formation, a great change had taken place in the fauna. We do not find a single Cretaceous mollusk* in the Eocene sea; indeed not only the species, but whole genera and families became extinct, and this not only in Switzerland, but wherever Tertiary formations are known. We seek in vain for the Caprinidæ, which filled Cretaceous rocks, and vainly search for Ammonites and Belemnites, which occupied so important a position in the older oceans and were luxuriantly developed in the Cretaceous seas. Of all the numerous forms of Cephalopods, only the genus *Nautilus* remains, which has continued to the present day, after having made its first appearance long before the Ammonites and the Belemnites. From the Nummulitic strata of Switzerland we know four species (*Nautilus zigzag*, Sow., *N. regalis*, Sow., *N. Sowerbyi*, Wilh., and *N. umbilicalis*, Desh.). Of the numerous marine univalves, the *Cerithiæ*, *Turritellæ*, *Rostellariæ*, *Neritinæ*, *Coni*, *Fusi*, and *Naticæ* are very largely represented. Among the bivalves the Oysters and Scallops are the most prominent; and with them are associated many genera which also occurred (although of different species) in earlier seas, such as *Cardium*, *Arca*, *Tellina*, *Corbula*, *Venus*, and *Cyrena*. *Stalagmium* and *Dreissenia* are seen here for the first time in Nummulitic rocks. Some genera are indicative of fresh water and dry land, such as *Planorbis* (*Pl. rotundatus*, Br., *Pl. planulatus*, Desh.?), *Limnæus* (*L. fusiformis*, Sow., *L. pyramidalis*, Desh., and *L. strigosus*, Br.), and *Helix* (*H. Ferranti*), which M. K. Mayer has discovered in the Bartonian of Ralligstöcke.

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* See Gümbel, 'Geognostische Beschreibung des bayerischen Alpengebirges,' p. 684.

Nummulites † are the animals specially characteristic of this period. A representation of the lenticular form of their shells is obtained by placing two watch-glasses together with their convex sides outwards; but sometimes the Nummulitic shells have a tendency to become spherical, or flat and disciform. The delicately granulated surface is often traversed by fine radiating lines (fig. 146, *b*). In the interior we find a number of spiral turns, divided by transverse partitions into chambers (figs. 145, 146). In the forms known as regular Nummulites the cavities of the chambers extend from the periphery on both sides to the umbilicus or axis of the shell, so that each convolution embraces the preceding ones on both sides (fig. 144). In a

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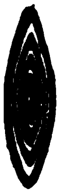
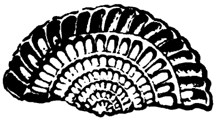
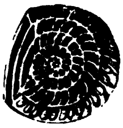
* Among the Polythalamia, *Rosalina ammonides*, Reuss, occurs both in the Nummulitic limestone and in the Cretaceous, whilst the Flysch and the Nummulitic limestone contain a great abundance of *Globigerina bulloides*, D'Orb., which is wanting in the Cretaceous.

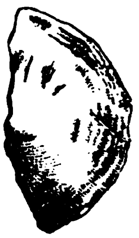
† The Swiss species of Nummulites are described in Rütimeyer's admirable memoir "Ueber das schweizerischen Nummulitenterrain," Denkschriften, &c. xi. 1850.

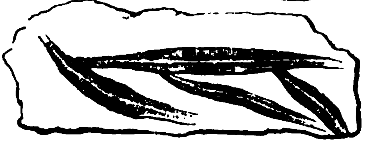
Fig. 144. Fig. 145. Fig. 146. Fig. 147. Fig. 148.











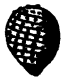


Fig. 149. Fig. 150.

Fig. 144. *Nummulina regularis*, Rütim., perpendicular section.
Fig. 145. Ditto, horizontal transverse section from the Fähnern.
Fig. 146. *Nummulina mammilla*, section; *b*, view from above.
Fig. 147. *Nummulina globulus*, Leym.
Fig. 148. *Hymenocyclus papyraceus*, Boub.
Fig. 149. Ditto, perpendicular section.
Fig. 150. *Chara Grepini*, Heer, from Delsberg.

second group, that of the irregular Nummulites, the chambers only reach half so far; and in a third group they are confined to the periphery. Each partition separating two chambers consists of two very thin laminæ, between which there is a very narrow space invisible to the naked eye (the interseptal space). The partitions and the external shell are perforated by numerous extremely fine pores, through which the animal enclosed within the shell probably pushed forth its slender feet (the pseudopodia) and thus came into contact with the outer world through the interseptal spaces. The transverse partitions are pierced by small apertures, forming a communication between the chambers, a sort of siphuncle which traverses the base of the spiral canal. With regard to the animal itself opinions differ, as there are no living Nummulites. Some think that each chamber contained a separate animal, so that a Nummulite represents a whole family of little creatures; whilst others maintain that only a single animal inhabited the shell, in which case it consisted of numerous segments each occupying a chamber. At any rate these animals seem to belong to the group of the Polythalamia, which has been already referred to (p. 202), although in size they far exceed both the Cretaceous forms and the Polythalamia of the present time.

Of the genus *Nummulina* we have about a dozen species; and one of these (*N. globulus*, Leym., fig. 147) occurs in extraordinary abundance. We find it throughout the Swiss Nummulitic region; and it sometimes forms whole beds of rock of wide extent. The nearly allied *N. mammilla*, Ficht. and Moll (figs. 146 and 146 *b*), and *N. regularis*, Rütim. (*N. Biaritzana*, D'Arch., figs. 144, 145), are also not uncommon; and *Nummulina mammilla* was figured by Lang more than 160 years ago as a "Swiss fruitstone."

These Nummulites were very widely distributed, for we find them not only throughout Central and Southern Europe, from the Pyrenees to Austria, but also in North Africa and in Asia, where they have been discovered in Asia Minor, Persia, Afganistan, on the Himalayas, and in Western Thibet (up to 16,500 feet above the level of the sea), the species being in part the same as in Switzerland. They must have contributed not a little to the marine fauna of their day, and by the innumerable myriads of elegant shells which they produced have added even to the solid crust of the earth. Essential aid was given also by the true Polythalamia, which occur very frequently in the Nummulitic as well as in the Cretaceous rocks, under the forms described as *Nodosariæ, Dentalinæ, Operculinæ, Alveolinæ, Triloculinæ*, and *Quinqueloculinæ*. The *Orbitolinæ* are especially abundant, and, as in the Cretaceous epoch (p. 214), they form here and there entire rocks. *Hymenocyclus papyraceus*, Boub., sp. (*Orbitolites discus*, Rütim., figs. 148, 149), is, with the *Nummulina globulus*, the most abundant animal of the Swiss Nummulitic formation; it possessed numerous chambers, which were arranged round a high central cell.

For the study of the Sea-urchins of the Nummulitic period, the neighbourhood of Yberg, at the head of the valley of the

Sihl in the Canton of Schwyz, is an important locality; nowhere else in Switzerland do these Sea-urchins exist in such numbers and variety. This part of the Eocene sea must have presented particularly favourable conditions for their development; and the fauna of these marine animals was at that time in a most flourishing state. Of the 32 species at present known from the Nummulitic formation of Switzerland, 24 have been collected in the vicinity of Yberg. The species belong to 14 genera, some of which (*Prenaster, Periaster, Hemiaster, Conoclypus, Echinanthus, Cassidulus, Nucleolites, Echinocyamus,* and *Pseudodiadema*) had continued from the Cretaceous epoch, whilst the others (*Manopneustes, Amblypygus, Echinolampas, Echinopsis,* and *Linthia*) made their first appearance here, and are chiefly limited to the Tertiary epoch. Most of the species are peculiar to Switzerland; but five of them are known from the "Calcaire grossier" of Paris, and three have been met with in the Crimea. The genera *Conoclypus* and *Linthia* include the principal types. In *Conoclypus* the lower surface of the test is flat or even concave, and the upper surface is oval or conical. The *Conoclypus anachoreta,* Ag., is one of the most abundant species at Yberg, and is 2 inches in diameter. The *Conoclypus conoideus,* Ag., is still larger, its diameter being sometimes as much as 6 inches; it is a very widely distributed species, occurring in Egypt and the Crimea. In the genus *Linthia* the ambulacral areas are bounded by a projecting border, and the whole test is closely set with small tubercles placed in slight depressions. The *Linthia insignis,* Mer., is about 3 inches in diameter, and is one of the most remarkable forms of the Swiss Nummulitic sea.

The Crustacea are represented by large Crabs. Splendid specimens of *Cancer punctulatus* have been found on the Niederhorn, near the Lake of Thun. The carapace is about 8 centimetres (3¼ inches) broad, and is armed with teeth on the anterior margin; the frontal margin is also furnished with four teeth. The upper surface of the carapace is very closely covered with fine pits. The long chelæ terminate in two strong fingers, which are but slightly curved. Near Brüllisau in the Canton of Appenzell, two species of Crabs (*Xanthopsis kressenbergensis,* Myr.?, and *Colpocaris bullata,* Myr.) have been discovered in the Nummulitic formation; and near Yberg the *Ranina Aldrovandi* is abundant.

The higher marine animals are but sparingly represented in the Swiss Nummulitic formation; but teeth and vertebræ of Sharks (*Carcharias tenuis*, Ag., and *Lamma plana*, Ag.) have been collected on the Fähnern.

Most of the species of animals of the Swiss Nummulitic sea have been found in other localities, and almost everywhere in the Eocene formations of France and Upper Italy; so that their geological age is determined.

The Nummulitic and Flysch rocks demonstrate the extension of the Eocene sea along the northern border of the Swiss Alps; and at the same time, by their thickness, amounting here and there to several thousand feet, they afford evidence of a time of formation occupying many thousand years.

How far the Eocene sea extended towards the north cannot be ascertained, as the sandstone deposits between the Jura and the Alps conceal the older formations almost throughout the low lands of Switzerland. At any rate the whole range of the Jura was then dry land; for not only do we find no traces of marine Eocene deposits from the Randen and the Lägern to the Swiss south-western boundary, but in various places we have evidence of a land formation in the pea-ore ("Bohnerz") and the remains of bones of land animals, to which attention should now be directed.

The pea-ore, or Bohnerz*, consists of rounded or bean-shaped grains of brown ironstone. Sometimes the grains are formed of numerous concentric layers—in this respect resembling oolitic grains, or pea-stones, produced in some bubbling springs by the formation of a deposit upon sand-grains kept in constant whirling motion. The grains of pea-ore, or Bohnerz, vary from the size of a pea to that of a hen's egg; they are in some places collected in great numbers, and are occasionally conglomerated into a cake several feet long and weighing some hundredweights. They are surrounded by party-coloured clays and white quartz-sand, the former often containing scattered fragments of the neighbouring Jurassic limestone.

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* [Prof. Jameson mentions "pea-ore," or "pisiform ironstone," as "Bohnerz." He describes it as filling hollows in the limestone, and states that, according to Mr. Mine-Counsellor Friesleben, "it occurs in an extensive bed of clay, which lies on the compact Jura limestone." It yields from 30 to 40 per cent. of iron. 'System of Mineralogy,' by Prof. Jameson, 1805, vol. ii. p. 331, Edinburgh.—EDITOR.]

The pea-ore, or Bohnerz, and the clays and sands surrounding it, fill the clefts and cavities of the White Jura, and here and there spread over the valley-bottoms. The pea-ore is always the lowest stratum; it is followed by the party-coloured clay which constitutes the principal part of the deposit. The thickness of the nests of ore is from 3 to 6 feet; in rare cases the deposit increases to 18 or 20 feet. The limestone-walls of the fissures which contain the pea-ore have undergone a considerable alteration. In many places they are so silicified that they produce sparks when struck with steel; in others they are coated with sulphuret of iron to such an extent that they acquire a red or brownish-red colour and a scoriaceous appearance; whilst in other places, again, the limestone has become dolomitic and acquired a lighter colour. In many places these fissures are of unknown depth, and probably indicate the places where springs have broken forth.

The pea-ore formation is spread over the whole of the Jura; but its chief development is in the Bernese Jura, especially the valley of Delsberg. In the valley of Laufen the iron-ores become scarcer and the deposits of clay and sand larger; but nests containing a larger or smaller quantity of ore have been worked at different times in the Cantons of Soleure, Basle, Aargau, Schaffhausen, and Zürich. It is everywhere deposited upon the White Jura or imbedded in its fissures. On the other hand, it is covered by the Miocene in many places, as near Flurlingen on the left bank of the Rhine, in the valley of Metzendorf, at Delsberg, and many other localities. It was formed, therefore, in the period between the White Jura and the Miocene. Formerly it was referred to the Lower Cretaceous*, under the supposition that, at the time when the Neocomian sea was spread over the south-western Jura, the pea-ore was deposited from hot springs in the dry land further to the east. It is certainly possible that the formation of the pea-ore commenced during the Cretaceous epoch, grains of pea-ore having been found in Cretaceous rocks in some places (as near Couvet in the Val Travers, according to Gressly); but that the largest deposits of pea-ore in Switzerland (such as those of Delsberg and Egerkingen) were formed in Eocene times, follows indubitably from the remains of plants and animals which have been discovered in those deposits, and from the circumstance that grains of pea-ore are found in the internal cavities of uninjured bones. These bones must consequently have fallen into the ferruginous water at a time when the pea-ore was formed; and as we shall find that the bones belong to Eocene animals, they give us the age of the formation.

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* By Gressly, in his "Observations géologiques sur le Jura soleurois," Denksch. schweiz. naturf. Gesellsch. v. 1841, p. 282; Quiquerez, "Recueil d'Observations sur le terrain sidérolitique dans le Jura Bernois," Denksch. xii. 1852; Studer, 'Geologie der Schweiz,' ii. p. 271. The Tertiary formation of the Swiss Bohnerz was first ascertained by Dr. Grepin (see "Notes géologiques sur les terrains modernes quaternaires et tertiaires du Jura Bernois, et en particulier du Val Délémont," Mémoires, xiv. 1855, pp. 49, 56).

That the pea-ore was produced in gushing springs is scarcely to be doubted, as similar formations still take place in such springs. If these springs were highly charged with iron and silica, the long-continued action of the mineral water upon the walls of the fissures could produce all the changes in them already referred to. The great amount of silica which the springs must have contained show that the water of the springs was at a high temperature.

The working of the pea-ore has formed an important industrial occupation for the inhabitants of the Jura; but it is to be feared that it will fail before very long. Ten years ago about 200 workmen were employed in the pits in the Bernese Jura; the ore (which gives from 40 to 44 per cent. of pig-iron) was smelted in five blast-furnaces; and there was an annual produce of about 20,000 hundredweight of iron, of the value of from 380,000 to 400,000 francs a year; but many pits are now out of work, owing to the diminution of their yield and the competition of Belgian and English iron. The numerous iron-works of the Jura chiefly obtained their raw material from these furnaces, and worked it up into bar-iron and agricultural implements.

The party-coloured clays are made into excellent red earthenware for cooking-purposes; under the name of "Porrentruy pottery" these articles are carried to all parts of Switzerland.

The white sandy clay is employed in the glass-works for making melting-pots.

If the pea-ore was produced by gushing mineral springs, the existence of dry land must be presupposed in the region of the Jura in Eocene times. The materials deposited by these springs would be in part carried away by streams. In many places (as on the Mauremont near Lasarraz, near Saint Loup, Delsberg, Egerkingen, and Obergösgen) numerous bones and teeth of vertebrate animals have been found in the pea-ore deposits of the fissures of the Jura. They are generally broken and thrown confusedly together; so that they were no doubt washed into the fissures; but at the same time they are so well preserved that they cannot have come from any great distance.

In these localities 61 species of animals* have been found—namely, 12 Reptiles and 49 Mammalia. The remains of the former are imperfect, and therefore difficult to determine; nevertheless two serpents, a few lizards of the size of lizards at the present time, an iguana, a crocodile, and several tortoises have been recognized. The crocodile (*Cr. Hastingsiæ*, Owen) resembles the Egyptian species; but it has a blunter snout, and thus seems an intermediate genus between a crocodile and a cayman. One of the serpents, judging from its vertebræ, was 10–11 feet long, and belonged to the family of the boas and the group of the pythons which now inhabit the forests of the East Indies. The second species is much smaller, but appears to be nearly allied to the former. The Chelonia are completely distinct from those of the Plattenberg (referred to at p. 248). The latter are marine turtles, whilst those of the Eocene Jura are land- and marsh-tortoises. Two species have their nearest allies in the existing genus *Emys*, and one in *Testudo*; whilst the largest and most remarkable species is a new form peculiar to this region, and has its nearest relatives in the tropical genus *Pyxis*. Its shortly oval carapace is about a foot long and nearly 8 inches broad; and the plastron was united to this so as to leave only two fissures before and behind, which could probably be closed by means of movable plates. From the resemblance of these to trapdoors the animal has received the name of *Dithyrosternon valdense*, Pict.

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* Most of the species from the Mauremont were discovered by Dr. C. Gaudin and Dr. P. de la Harpe, and are now in the Museum at Lausanne. Some were collected by Prof. Morlot and Dr. Campiche. They have been worked out by Pictet (see 'Mémoire sur les Animaux vertébrés trouvés dans le terrain sidérolitique du Canton de Vaud,' by Pictet, Campiche, and De la Harpe). The animals of Egerkingen were discovered by the Rev. M. Cartier. and those of Gösgen by C. Mösch; these were studied by Prof. Rütimeyer (see "Mammifères éocenes du Jura Suisse," Denkschr. der schweiz. naturf. Gesellsch. xix. 1862). The fossil bones found by Dr. Grepin in the neighbourhood of Delsberg are for the most part not yet determined; and this is the case also with some abundant materials collected near La Sarraz since the last publication of Gaudin and De la Harpe. We may therefore expect a considerable addition to the number of the species.

The Mammalia are still more interesting; for these most perfect Vertebrata are here met with for the first time in Switzerland, and the great number of species is very surprising. We have already (p. 149) mentioned that this class of animals occurs in older formations in the United States, Germany, and England; and there can be no doubt that it was further developed during the Cretaceous epoch, although we know of no species belonging to that period; but it is certain that in Tertiary times Mammalia were widely distributed. From previous periods we know only a few species; and these are very rare, and are chiefly small creatures belonging to the Marsupials.

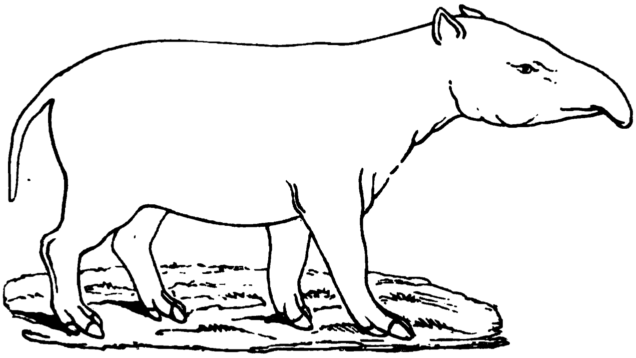
The Swiss Eocene Mammalia belong to 5 orders. The Pachydermata include 24, the Ruminantia 12, the Rodentia 4, the Carnivora 8, and the Quadrumana 1 species. In this distribution of the species the Eocene fauna differs from the Swiss fauna of the present day; for the latter includes no Quadrumana, and the Pachydermata are represented only by a single species (the wild boar). The Eocene species are all distinct from those now living; and of the 25 genera to which they are referred, only 4 (*Sciurus*, *Viverra*, *Spermophilus*, and *Vespertilio*) have continued to modern times. Some of the fossils cannot be satisfactorily determined, owing to their very imperfect preservation.

Among the Pachydermata, *Palæotherium* and *Lophiodon* are the two most important genera, and include the greatest number of species. The *Palæotheria* had the general form of the Tapirs;

the elevated nasal bone shows that, like the tapirs, they had a short movable proboscis; and the incisor teeth and elongated pointed canines are similar in form to those of the tapir, whilst the molars resemble those of the rhinoceros. Their feet had three toes.

Palæotherium magnum, Cuv. (fig. 151), was as large as a horse.

Fig. 151.



Palæotherium magnum, Cuv. Restored.

It is a widely distributed species, having been found in England, France, and Swabia, as well as in Switzerland (at Grossgösgen). *P. medium*, Cuv., an equally abundant species, was about the size of a pig. It is common at Gösgen and at Mauremont, and also occurs at Delsberg. *P. crassum* and *P. latum*, Cuv., are a little smaller, and have comparatively shorter and stouter legs.

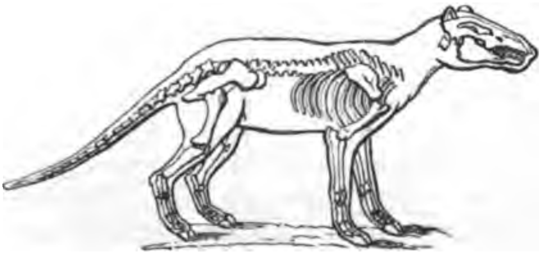
In the *Palæotheria* each side of each jaw has seven molars, whilst in the nearly allied genus *Lophiodon* there are only six molar teeth. Of this genus eight species have been discovered at Egerkingen. *L. buxovillanus*, Cuv., and *L. medius*, Cuv., were of the size of the Indian tapir; and *L. tapiroides*, Cuv., was about one fourth larger.

Anchitherium siderolithicum, Rütim., from Egerkingen, is to be regarded as the precursor of the horse, belonging, like it, to the family of Solidungula, although each foot contains two rudimentary lateral toes besides the large middle one. It is a form intermediate between the equine and tapirine mammals.

Hyopotamus Gresslyi, Myr., and *Chasmatherium Cartieri*, Rütim., from Egerkingen, are more nearly allied to the Pigs, as are also *Hyracotherium siderolithicum* and *Rhagatherium valdense*, Pict., from Mauremont. The last-mentioned was an animal about the size of a badger, with a long tapering snout and projecting, recurved, two-edged canines separated by a space from the other teeth. *Chasmatherium* is known only by a few teeth, and appears to be very nearly allied to the preceding; whilst *Hyracotherium* approaches *Anthracotherium*, which we shall meet with in the next epoch.

The Eocene fauna does not comprise those forms of ruminants which chiefly characterize the existing fauna, such as deer, antelopes, oxen, &c. The two most important types, *Anoplotherium* and *Xiphodon*, approach the Pachydermata, and were formerly referred to that group. *Anoplotherium commune*, Cuv. (fig. 152), which has been discovered near Gösgen, was about the size of a fallow deer. It represents a very important animal type, displaying many characters in the dentition and skeleton which occur in the ruminants only in the embryonic state. It seems to constitute a bond of union in which the characters of various forms of animals are still united. As in the *Palæotheria*, there are

Fig. 152.

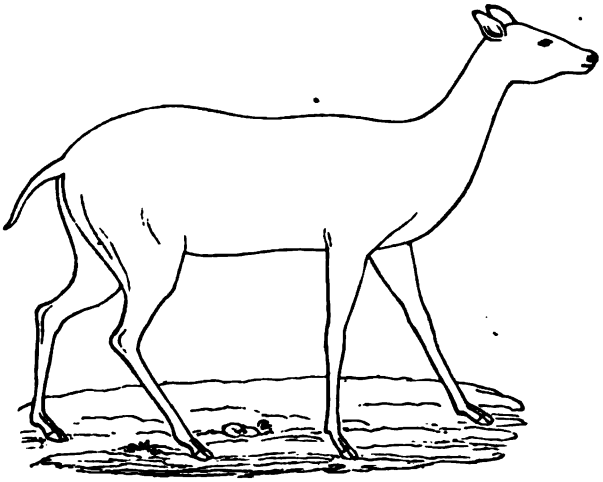


Anoplotherium commune, Cuv. Restored.

seven molars on each side of each jaw; but the canines do not project, and the teeth form a closed series. The form was more slender and slighter than in *Palæotherium*; the feet had two toes, which were furnished with hoofs; and the tail was very long and powerful. Its mode of life is supposed to have been similar to that of the hippopotamus.

Xiphodon gracile, Cuv., from Soleure, had a much more elegant form, resembling the Antelopes in this respect. It had a small head, elongated and tapering in front; the teeth stood in uninterrupted series in the jaws; the well-proportioned body was supported upon long and slender legs, terminating in two-toed feet; the tail was small, and formed of thin vertebræ (fig. 153). *Xiphodon gracile* was of the size of a chamois; but in its form, and in the structure of its bones and teeth, it is most nearly allied to the musk-deer. This applies also to *Amphitragulus communis*, Aym., from Egerkingen, the molar teeth of which are almost exactly like those of the musk-deer which

Fig. 153.



Xiphodon gracile, Cuv. Restored.

inhabit Central Asia and the Sunda Islands. The much smaller animals forming the genus *Dichobune* had a similar appearance. These were elegant little creatures of the size of our hares and rabbits; four species have been discovered at Egèrkingen, and the same number in the Canton of Vaud.

Of the Rodentia the remains are very imperfect; but they prove that at this period the forests were enlivened by small squirrels (*Sciurus* and *Spermophilus*), and that the Mice were represented by a small species (*Theridomys siderolithica,* Pict.), approaching to the American group of the Psammoryctins.

That the peaceful herbivorous denizens of the old Eocene forests had their enemies is shown by the remains of Carnivora which have been found in the same localities. But they are of small species, and the large predacious animals do not make their appearance until a later period. We have some small civets (*Viverra* and *Proviverra,* Rütim.), a fox-like animal (*Cynodon helveticus,* Rütim.), and two or three species of *Amphicyon.* The latter resemble the dog in the structure of the skull, but they were of a stronger build and had a longer tail.

There was also a bat (*Vespertilio Morloti,* Pict.), of the size and form of the common species (*V. murinus*) of the present day, which leads Prof. Heer to infer the existence of insects on which it fed.

The most remarkable animal from Egerkingen is a species of monkey (*Cænopithecus lemuroides,* Rütim.), for the discovery of which we are indebted to the indefatigable researches of M. Cartier. Only a fragment of the upper jaw with three molar teeth has been found; but the acumen of Rütimeyer not only enabled him to determine the order to which the animal must have belonged, but also to refer it with much probability to its proper place in the system. In its dentition this Swiss monkey resembled both the African lemurs and the American howling monkeys (*Mycetes*); but as the structure of the maxillary bones comes nearest to the latter, they must be regarded as its nearest allies. Judging from the teeth, it was about the size of the red howling monkey (*Mycetes seniculus*); but it forms a peculiar genus (*Cænopithecus*), which, according to Rütimeyer, combines the characters of the lemurs and of the marmosets and howlers of the New World.

There is a great analogy between the mammalian fauna of the Swiss Jura and that of the Paris basin, which has been rendered so famous by Cuvier's immortal works. In both localities the species are for the most part the same; and as many of them have also been discovered in the Eocene of England (Isle of Wight) and in Germany, they were probably spread over a great part of the European continent of that period, and have given a special character to the fauna. It is worthy of notice that the animals of Egerkingen (especially the species of *Lophiodon*) agree with those of the "Calcaire grossier" of Paris, while the animals of Mauremont and Grossgösgen resemble those of the Parisian gypsum beds. As the latter belong to the uppermost stage of the Eocene, and the "Calcaire grossier" to a lower one, it is very probable that the animals of Egerkingen are of an earlier age than those of the other localities, just as the marine animals of the Alpine Nummulitic formation reproduce the faunas of several sections of the Eocene period.

A fauna so varied and chiefly composed of herbivorous animals necessarily implies an abundant vegetation; but this has disappeared in Switzerland, almost without leaving any traces. The coal-deposits of the Nummulitic formation alone give us some evidence of its nature in the region of the Alps; and a few fruits of *Chara,* discovered by Dr. Grepin in the Bohnerz or pea-ore deposits of Delsberg, testify to the nature of some plants in the Jura. The *Charæ* belong to three species, one of which (*Chara helicteres,* Br.) is characterized by its shortly oval and comparatively large fruits, and a second (*Ch. Grepini,* Heer, fig. 150, p. 268) is remarkable for the elegant tubercles with which the fruits are covered. Fruits with similar tubercles are found in the Eocene deposits of the Isle of Wight. These plants lived in fresh water, and they give us no information as to the land-flora of that time. Traces of the Eocene land-flora occur in Monte Bolca, in Provence, in the older brown-coal deposits of Saxony, and in the Isle of Wight.

As Monte Bolca forms part of the Swiss Alpine system, Prof. Heer is justified in assuming that, at the time of the Swiss Nummulitic sea, the region of the Alps was clothed with a vegetation similar to that which has now been taken out of the limestone rocks of Monte Bolca. This flora has many points of connexion with that of the Upper Cretaceous, but yet it has a different character. The Ferns, which were still numerous in Cretaceous times, have become scarce; and the Cycads have entirely disappeared. The Gymnosperms, although still abundant, no longer occupy their former preponderating position. The general character of the flora is Indo-Australian; but the Australian types are less predominant, and are replaced by the Myrtaceæ and Sandal-woods rather than by the Protaceæ. In the fishes of the sea which washed these shores, as in the land-flora, we see the tropical Asiatic type. The shores were clothed with evergreen trees and shrubs. Thick-leaved fig-trees like the Indian-rubber tree (*Ficus elastica*), long-leaved *Eucalypti*, and leathery-leaved Myrtle and sandal-wood trees, alternate with pinnate-leaved Guaiacums and Sapindaceæ, and with curious trees of the genera *Drepanocarpus* and *Pterocarpus*, of which the pinnate leaves and spirally twisted capsules have come down to the present time. Spiny *Cæsalpiniæ* expanded their elegant bipinnate leaves, and must have formed a singular contrast to the rigid-leaved *Grevilliæ*, *Hakeæ*, and *Dryandræ*, and the nearly leafless *Leptomeriæ*. The latter genera, with *Zizyphus antiquus*, Heer, and *Aralia primigenia*, probably formed the underwood of the forest, whilst the *Poranæ*, *Bignoniæ*, and *Jacarandæ* were fine climbing plants, which no doubt garlanded the trees and shrubs in the same way as their relations do in the tropical forests of the present day. Palms also were not wanting; but only the leaves of a small fan-palm and two or three spathes and fruits resembling those of the cocoa-palm have as yet been found. Monte Bolca, like the Swiss Eocene Jura, was inhabited by a large serpent.

The white clay of Alum Bay, in the Isle of Wight, contains a flora similar to that of the limestones of Monte Bolca. Here we find large leaves of figs and laurels, the notched foliage of the *Araliæ* (*A. primigenia*), the sharply toothed leaves of evergreen oaks and *Dryandræ*, the fine twigs of the *Sequoia*, and the elegant pinnate leaves of the *Cassiæ* and *Cæsalpiniæ*.

RECAPITULATION.

Starting from the Glaris slates as the best-known strata of the Swiss Eocene period, and determining their geological position, Prof. Heer has extended his view over the whole of the formations deposited in Switzerland during that epoch. The Eocene marine deposits have been shown to rest directly upon the Upper Cretaceous wherever the stratification remained undisturbed; and the animals which they contain agree with those of the Eocene period in other countries. The deposits of the Eocene period are best developed in the vicinity of Paris and London and in the Isle of Wight; and the careful study of their strata and of their organic contents has led to the very numerous beds being arranged in three groups—the Lower, Middle, and Upper Eocene.

To the Lower Eocene belongs the London Clay; and in the Middle Eocene are comprised the overlying sandy and argillaceous strata to which Sir Charles Lyell gives the name of Alum Bay and Bournemouth beds, as well as the green clayey sands of Bracklesham Bay (near Chichester) and the Bagshot sands, corresponding with the "Calcaire grossier," or compact fragile limestone of Paris.

To the Upper Eocene, according to Sir Charles Lyell, belong the series of sands and clays seen almost horizontal in Barton Cliff, near Lymington, Hampshire, which correspond with the sands of Beauchamp in the Paris basin. Above the Barton beds are the three Isle-of-Wight series of Headon, Osborn or St. Helen's, and Bembridge; and the Bembridge beds are represented in the Paris basin by the gypseous series of Montmartre.

Having thus determined the leading English and French Eocene deposits, a comparison of the Swiss Eocene formations with them will lead to the following results:—

1. Middle Eocene, the Paris "Calcaire grossier," belongs to the same age as the Swiss Nummulitic fauna of the Cantons of Unterwald, Schwyz (Yberg, &c.), St. Gall, and Appenzell, and the Mammalia of Egerkingen.

2. Lower stage of the Upper Eocene. Bartonian beds in Hampshire correspond with the Swiss Nummulitic fauna of the Ralligstöcke.

3. Upper stage of the Upper Eocene. Paris gypsum agrees with the Mammalian fauna of Mauremont and Obergösgen.

Over the Nummulitic deposits of Yberg are the fucoidal shales of Yberg, which must therefore belong to the Upper Eocene formation.

From the foregoing observations and data the following Table of the Eocene deposits has been arranged.

Table of Eocene Deposits.

Switzerland.	France.	England.	Italy.
	Upper	Eocene.	
Fauna of Mauremont, Soleure, and Obergösgen; Fucoidal shales.	Gypsum of Montmartre.	Bembridge beds.	Macigno of Liguria and Tuscany.
Nummulites of the Ralligstöcke.	Sands of Beauchamp.	Barton clay.	Nummulitic formation of Nice.
	Middle	Eocene.	
Fauna of Egerkingen, nummulitic formations of the Canton of Schwyz, &c.	Calcaire grossier. Soisson's sands.	Bagshot and Bracklesham beds. Flora of Alum Bay.	Monte Bolca. Nummulitic Greensand of Belluno.
	Lower	Eocene.	
	Clay near Dunkirk. Plastic clay, sands of Bracheux (Beauvais).	London Clay. Reading and Woolwich series, Thanet sands.	

During the Eocene period the configuration of Europe was essentially modified. From Upper Cretaceous times (the Cenomanian) the sea in Europe has constantly diminished. The Swiss basin (see the map, p. 175) gradually became narrower, the northern or Jurassic shore gradually advancing, as is proved by the absence of all the younger Cretaceous deposits in the district of the Jura. In Eocene times there remained only a comparatively narrow strip of sea along the Alps, in which the Nummulitic and Flysch rocks were deposited. It is remarkable that this narrow band can be traced through Bavaria and Austria as far as Vienna. But south of the land which we have called the Penninocarnic island (p. 175) we find Eocene deposits from the Adriatic to the Lake of Lugano; and, indeed, the greater part of Italy was then under water. On the other hand, Greece formed a long narrow peninsula like Italy at the present day; and this was directly united with the Penninocarnic land through Dalmatia and Carinthia.

After the Cretaceous epoch the sea retreated still more in the north and west of Europe. Whilst in Cretaceous times the region of Paris lay in the midst of a great ocean, which spread over a great part of France (see the Cretaceous map, p. 175), it was now brought to the coast, as appears unmistakably from the mixture of terrestrial and marine animals contained in such abundance in the Eocene deposits of that locality. This applies also to the Isle of Wight. Here, as in the Paris basin, marine and freshwater deposits alternate; and therefore the level of the sea must have undergone several oscillations during this period.

Hence, as early as the Eocene times, Europe appears to have been a considerable continent, intersected by many arms of the sea, presenting favourable conditions for the development of a luxuriant flora and fauna. The latter indicate a nearly tropical climate. The evergreen forests, with their Figs and Sapindaceæ, their Myrtles and Palms, agree very well with the numerous tapir-like *Palæotheria,* the musk-deer, and the monkeys which dwell among them. In like manner the marine animals, the fishes of Matt, and the Mollusca of the Nummulitic rocks indicate a decidedly warm climate; and the Flysch alone, by its complete desolation, presents a wonderful and inexplicable contrast to the other phenomena of this epoch.

As the useful products of this age we have the slates of Matt and the pea-ore, the working of which furnishes occupation to many hands. The coals of this formation are of little importance; but the dark sandstones are much used for building. The soil of the Flysch is fertile, because the rock is easily weathered and broken up, and perhaps also because it contains traces of phosphoric acid; but the pea-ore soil is unfavourable to cultivation, and even trees will not flourish upon it.

CHAPTER VII.

MIOCENE PERIOD,

OR

MOLASSE PERIOD OF SWITZERLAND.

In the earlier part of this work the undulating country between the Jura and the Alps has been regarded as an ancient marine bay, inaccessible to modern geological researches. The depths of that arm of the sea have been covered over with such masses of marls and sandstones that the older rocks only appear on the margins of the sea-basin. Some of the sandstones are hard and compact; others are soft, or they are found as beds of sand. In the Canton of Vaud these strata have received the name of "Molasse," a name which has been extended to all the formations* of the period.

About 152 square geographical miles are comprised in the Molassic district, being nearly one fifth of the area of Switzerland. On the south the Molasse is stopped by the zone of Flysch and the Nummulitic deposits, which have been already described; it touches the Cretaceous rocks only in a few localities. On the north it is bounded by the Jura and by the heights of the Cretaceous formation belonging to the Jurassic chain; so that it occupies the lowlands of Switzerland.

The depths of several valleys of the Jura are filled with Molasse, where it also overlies the Eocene ferruginous nodules called pea-ore. Along the Alps the Molasse has been so much upheaved that a portion of it dips towards the Alps beneath Alpine deposits, whilst another part dips northwards and passes into a horizontal position.

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* See Professor B. Studer's 'Contributions to a Monograph on the Molasse,' Berne, 1825. This work, as well as the second volume of Prof. Studer's 'Geology of Switzerland,' are two of the best publications to aid in the study of the Swiss Molasse.

These conditions of stratification clearly show the Molasse to be more recent than the Eocene formation: it belongs to the period called Middle Tertiary or Miocene, which has the same signfication as Molasse.

The deposits of the Miocene[*] period are of great thickness, and rise on the borders of the Alps into considerable mountains, such as the Speer (6021 feet) and the Righi (5541 feet). Towards the north the Miocene country is depressed, and the water in the rivers and brooks consequently flows off in a northerly direction, and has excavated deep and broad valleys.

The rocks which constitute the Miocene are sandstones, marls, conglomerates, and limestones.

The *Sandstone* is of a grey colour, and consists of granules and splinters of quartz, with felspar and other hard minerals, united into a tolerably uniform mass by a marly cement. Many varieties occur, produced by the varying proportion of the marly cement to the harder minerals and by the more or less intimate union of the mixture. In many places (as near Berne, Lucerne, at the upper part of the Lake of Zurich, and near Rohrschach) it furnishes excellent building-stone, which, however, differs greatly in different localities: near Berne the sandstones are quite soft when fresh, but harden in the air, and are therefore easily worked; those of Bäch split into large slabs, the surfaces of which are covered with blue marl and shining spangles of mica; whilst those of Bollingen break up into large blocks. Here and there in the soft Molasse there are large solid masses of the most various forms, which often project like columns or cones from the weathered rock. A still more remarkable variation is presented by the shell-sandstone, which consists in great part of comminuted bivalve shells, together with green grains as large as peas, cemented by a hard sandstone-mass. The shell-sandstone spreads in the direction of the Jura from the Canton of Vaud to the Lägern; it furnishes highly prized stone for the basins of fountains and for pavements, and is worked in many places, such as Würenlos, Mellingen, Othmarsingen, Lenzburg, &c.

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[*] [The lower Tertiary beds received the name of Eocene from ἠὼς, eos, *dawn*, and καινὸς, cainos, *recent*—because the fossil shells of that period contain an extremely small proportion of living species, which may be looked upon as indicating the dawn of the existing state of the testaceous fauna, no recent species having been detected in the older or secondary rocks. The term Miocene (from μεῖον, meion, *less*, and καινὸς, cainos, *recent*) is intended to express a minor proportion of recent species of Testacea; the Middle Tertiary beds form the Miocene division. Pliocene sets of strata contain a comparative plurality of recent species. ('Elements of Geology,' by Sir Charles Lyell, Bart., F.R.S., 1871, p. 120.)—EDITOR.]

The *Marls* are often interstratified with the sandstone, and frequently pass imperceptibly into it. In the marine Molasse they are generally dark grey; whilst in the freshwater formation they are often red, yellow, and blue, forming party-coloured bands in the rock.

The *Conglomerate*, or "Nagelfluh," consists of pebbles of the most different sizes cemented together by a sandy marl or sandstone. Various kinds are distinguished, according to the nature of the pebbles and the cement uniting them. In the *variegated conglomerate* the pebbles consist principally of granite, porphyry, gneiss, and quartz rock; and in the *calcareous conglomerate* the limestone and sandstone pebbles predominate. It is remarkable that most of the pebbles of both kinds differ from the rocks existing in the neighbouring high mountains; so that the pebbles cannot have been derived from these rocks. The limestone pebbles resemble the Lias limestones of the Vorarlberg and the yellowish-white limestones of the Upper Jura; the red granitic and porphyritic pebbles are like the strata of the Black Forest. The pebbles often show polished surfaces, and are sometimes crushed; the limestone pebbles not unfrequently show deep rounded impressions, into which neighbouring pebbles fit accurately. The mode of production of these cavities is still a mystery: perhaps they were produced by the long-continued friction of the stones under water.

A third kind of conglomerate is called *spongy*. Its pebbles are derived from the Swiss district; they are loosely united by sandy masses, often leaving vacant spaces between them. They have no deep impressions, but are sometimes striated with furrows. Bands of loose sandstone often alternate with the pebble-beds. The spongy conglomerate forms the highest top of the Uetliberg and of the hills of the Au; it also occurs in various places in the Cantons of Aargau and Berne, and at the summit of the Schienerberg near Œningen. Its formation, however, probably did not take place in the Miocene period, but at a later epoch, whilst the variegated and calcareous conglomerates certainly belong to the Molasse or Miocene.

The conglomerate is most developed along the southern border of the Molasse-country in the Upper Emmenthal, between the Lake of the Four Cantons and the Lake of Zug, and from Toggenburg over the chain of the Hörnli into the environs of Kyburg and Elgg. The Napf, Righi, and Speer may be mentioned as its three central points. All over this region enormous masses of rolled pebbles and sand have been transported. The Napf forms a central point for the *variegated conglomerate.* According to Studer it contains rocks of hornblende mixed with talcose quartzite (silicate of magnesia) or micaceous quartzite. The quartzite pebbles contain gold-dust; they probably furnish the auriferous sand of the Emme and the Aar, which was already worked in very ancient times. The variegated conglomerate also occurs on the Righi near the Staffel, at Rothstock and Dossen, on the Rossberg, at Walchwylerberg, the Hohe-Rhonen, and in the Canton of Appenzell, especially in the neighbourhood of Gäbris.

The *calcareous conglomerate* extends from the Lake of Geneva through the Canton of Friburg to the lower part of the Gurnigel. In the Emmenthal it is enclosed by variegated conglomerate; on the Righi and the Speer, limestone pebbles form the principal mass of the mountains. In the chain of the Hörnli the majority of the pebbles consist of grey and yellowish limestones, probably belonging to the Lias of the Vorarlberg, as one of them contains a specimen of *Ammonites Regnardi,* which is characteristic of the Vorarlberg Lias; these are mixed with pebbles of red sandstone, resembling that of the Lower New Red Sandstone of the Black Forest. The mass is interspersed with pebbles of white and reddish granite, porphyry, gneiss, red quartz, and hornstone. A peculiar calcareous conglomerate is quarried in the neighbourhood of Rüti near Hüllenstein; it is employed, on account of its great hardness, for basins for fountains and for pedestals. This is called "Appenzell granite" by the Zurichese masons. It consists of a firmly cemented mass of pieces of black limestone with some quartz-pebbles; it may be traced from the neighbourhood of Feldbach as far as Herisau.

Conglomerate (or "Nagelfluh") is met with in the Jura as well as in the Alps. It occurs in the Jura of the Cantons of Berne and Soleure, as, for instance, in the valley of Court, where it consists of variegated granites and porphyries and dark Alpine limestone, singularly enough without any intermixture of stones proceeding from the Jura itself. In the Delsberg the conglomerate is formed of loosely bedded Jurassic limestones and of red sandstones, granites, and rocks foreign to the district and derived from the Vosges and from Steinbühl. Above Breitenbach a sandstone, a red porphyry, and granite may be noticed, which probably came originally from the Black Forest. In the Jura of the Cantons of Berne, Soleure, Basle, Aargau, and Schaffhausen a calcareous conglomerate is very widely spread, here and there forming beds of great thickness. The pebbles consist of the various limestones of the Jura; they range in size from that of a pea to that of a man's head, and are generally united by a yellow or reddish calcareous sandstone. According to M. C. Mösch the conglomerate of the Canton of Schaffhausen consists chiefly of oolites from the Canton of Aargau, which therefore appear to have come from the east.

That this Jurassic conglomerate belongs to the Miocene epoch is proved by the teeth of a *Mastodon* (probably *M. tapiroides*), which M. Mösch has discovered in it on the Bötzberg.

In the deposits of the Jurassic and Cretaceous epochs the proportion of limestone was large; but in the Miocene period limestone forms only a subordinate part of the series. The conditions were then wanting for the production of vast limestone rocks—namely, a widespread sea with its myriads of little workers, acting for thousands of years, all aiding in building up the solid crust of the earth.

Small limestone deposits, however, are not unfrequent in the Molasse. At Porrentruy there occurs a marine limestone which is sometimes white and sometimes brown, and was probably contemporary with the Tongrian stage. But generally the Miocene limestones are light-coloured (and frequently marly) freshwater beds, which may be traced on the slopes of the valleys for considerable distances, and are worked and burnt for lime in many places. They were probably formed in small lakes and pools, and afford evidence of the distribution of these pieces of water.

Frequently the Molasse contains lignite; and it is very probable that lignite-beds were enclosed in the upper and lower Miocene strata of a large part of Switzerland. Unfortunately, the lignite is nowhere of any considerable thickness. Almost every year lignites are said to have been discovered in fresh places; and very often fruitless attempts are made to work them. It is only in a few localities that they can give a profitable result or last for any length of time, such as the pits on the Paudèze near Lausanne, those on the northern slope of the Sonnenberg near Lucerne, on the Hohe-Rhonen, and at Rufi near Schännis, and those of Käpfnach near Horgen, and of Elgg and Herderen in the Canton of Thurgau. Of all these pits that of Käpfnach is the oldest, and the only one which has continuously furnished a considerable quantity; but this is due less to the thickness of the bed, which averages only 8·75 inches, than to its position near the lake affording favourable conditions for carriage, and the excellent management of its director, M. C. Stockar-Escher. In 1848 the yield amounted to 9388 cwt., and in 1849 to 11,386 cwt., giving a net profit of 1818 francs. In 1861 the total yield of saleable coal was 126,242 cwt., equivalent to 6800 cords of fir wood (the cord being equal to 108 cubic feet), or 278,000 cwt. of paper coal and 72,000 cwt. of coal. The number of workmen was 83; and they worked out nearly 4 acres of the deposit, the square fathom yielding about 26·48 cwts. The net profit amounted to 17,757 francs. In 1862, 103,749 cwt. were obtained from 4003 square fathoms of the bed, and the sale produced about 76,000 francs. An important accessory product of this pit is the dark-coloured marl enclosing the lignite, which is much prized for manuring the vines. One hundred and forty barge-loads of it were employed for this purpose in 1861, and 156 similar loads in 1862. The coal-bed of Horgen is probably continued through the whole mass of the Horgeregg, as it reappears on the other side of the mountain on the same stratigraphical horizon, in the Sihlthal (at the small pit of Steinkratten).

If we examine the Miocene stratification, and the fossil plants and animals belonging to the rocks of that period, five sets of strata are observed. Of these, the oldest deposits (1) form the *Tongrian* stage, containing marine animals, and forming the Molasse of the Canton of Basle and of Porrentruy. It was formed in an arm of the sea, which extended from Alsace to Basle, and over the Ferret to the neighbourhood of Porrentruy and Delsberg. No deposits of this period are known in the interior of Switzerland, unless we may connect with it the uppermost and most recent strata in a band of Eocene formation stretching from the Dent-du-Midi and the Diablerets into the Canton of Berne.

The marine animals, which are found on the Dent-du-Midi up to 10,940 feet above the sea-level, include, besides Eocene species of Nummulites and Mollusca, a number of forms of the lowest stage of the Miocene, to which they are consequently referred by M. K. Mayer, whilst other geologists (such as MM. Hébert and Renevier) place them in the uppermost Eocene set of strata.

2. The second Miocene stage is called the *lower brown-coal formation*. It is also known as the *Aquitanian stage*, a rich marine fauna belonging to it having been preserved in western France, the ancient Aquitania. It no doubt forms a considerable deposit over the whole of the Swiss Molasse district; but in most places it is covered up by more recent formations of the Miocene period. In western Switzerland, where it is most largely developed, it consists, in the first place, of beds of variegated marl (the *red Molasse*) sometimes attaining a thickness of 1000 feet, then of sandstones and marls containing lignites, as on the Lake of Geneva, where there are rich accumulations of organic remains at the Paudèze and at Monod (near Chexbres). In the east of Switzerland the lignites of the Hohe-Rhonen and the Rüfi near Schännis belong to this stage, when the sea had disappeared from the country, or only remained here and there along the Alps in the form of lagoons of brackish water. A lagoon of brackish water existed in the Lehmeren ditch near Ralligen, the deposits of which contain lower Miocene land-plants, together with brackish-water animals.

In the environs of Lausanne the Lower Brown-Coal formation is overlain by (3) a *grey Molasse* stage, several hundred feet in thickness, which was formed in fresh water. It may be traced over the whole of Western Switzerland, and also along the Alpine zone to the Cantons of St. Gall and Appenzell, where it forms the sandstones of the Mönzlen and the Ruppen, and attains in some places a considerable thickness.

Upon this grey Molasse a marine formation was deposited, containing marine Mollusca and sharks' teeth. It constitutes the 4th or *Helvetian* set of the Swiss Miocene strata. It may be traced from the Perte-du-Rhône and the shores of the Lake of Geneva, where, above Lausanne, it attains an elevation of 1220 feet above the surface of the lake (or 2470 feet above the sea-level); it may be traced onwards through the Cantons of Vaud and Friburg, and along the whole chain of the Jura to the Lägern and the Randen. It also appears along the Alps, forming a band of marine sandstones, which may be followed from Rorschach through St. Gall, Bäch, Lucerne, and the Canton of Berne to the Saane. This zone has been distinguished as the *subalpine Molasse*, whilst that which follows the chain of the Jura is known as the *Shell-sandstone*. It was evidently the strand, on which the animals living in the shallow sea were accumulated in great quantities by the breaking waves. Whether the Miocene basin between these two marine bands was covered by sea-water is not yet proved, as more recent freshwater sandstones are deposited over it; but probably at that time the sea stretched from the Alpine zone to the Jura, although only the margins of the deposits then formed are accessible to modern observation. It is worthy of notice that this sea penetrated in distinct fjords into the valleys of the Jura, and produced rocks of marine origin in La Chaux-de-Fonds and in the Delsberg.

In Eastern Switzerland the marine Miocene is covered by a purely freshwater formation, the 5th and uppermost stage of the Swiss Miocene series. It overlies and conceals all the sandstones formed by marine deposits. The sea had then permanently disappeared from Switzerland; for no traces of later marine formations exist anywhere. The soft sandstones, marls, and freshwater limestones deposited at this period form the principal subsoil in the east of Switzerland, so far as it belongs to the Molassic district. The pleasant hill-country of the Cantons of Thurgau and Zurich is entirely formed by these beds, such as the Zurichberg, the Uetliberg, the Albis, the Irchel, and the whole of the Hörnli chain. In Western Switzerland, on the contrary, the grey and marine Molasse form the uppermost beds, and formations of the 5th stage have at present been only recognized in the freshwater limestone of Locle and La Chaux-de-Fonds, at Montavon, and at Vermes in the Delsberg. The Molasse of this stage, like that of the Aquitanian stage, contains a deposit of lignite to which the coals of Käpfnach, Elgg, Herderen, and Niederutzwyl belong; and from this circumstance it has been called the *Upper Brown-Coal formation.* It is also known as the *Œningian stage,* as the calcareous marls of Œningen, which contain the richest collection of organic remains in Europe, were formed at that period.

The following Table exhibits the series of the different stages of the Swiss Miocene period.

UPPER MIOCENE PERIOD.

UPPER FRESHWATER MOLASSE.

V. UPPER BROWN-COAL FORMATION.

Œningian Stage.

Schrotzburg, Wangen, Steckhorn, Berlingen, Herderen, Niederutzwyl, Kilchberg in the Toggenburg, Irchel, Veltheim, Elgg.

Uetliberg, Zürichberg, Albis, Käpfnach.

Locle, La Chaux-de-Fonds, Montavon, Vermes.

MIDDLE MIOCENE PERIOD.

MARINE MOLASSE.

IV. HELVETIAN STAGE.

Subalpine Molasse.

Rorschach, St. Gall, Steingrube, Bäch, Lucerne, Berne, Belpberg, Münsingen, Corbière, La Chaux-de-Fonds.

Shell Sandstone.

Rorbas, Buchegg, Haarbuch, Glattfelden, Steinbuck near Ehrendingen, Mettmenhasli, Hexenstein, Kilwangen, Würenlos, Mellingen, Othmarsingen, Lenzburg.

Soleure, Schnottwyl, Bucheckberg, Büren, Nidau, Friburg, Tour de la Molière, above Lausanne, Perte-du-Rhône, Altishofen, and on the Wellberg, Honig near Wytelingen, Canton of Lucerne.

LOWER MIOCENE PERIOD.

LOWER FRESHWATER MOLASSE.

III. GREY MOLASSE STAGE.

Ruppen, St. Gall, Oberägeri, Aarwangen, Eriz, Delsberg, Moudon, Payerne, Lausanne.

II. LOWER BROWN-COAL FORMATION.

Aquitanian Stage.

Hohe-Rhonen, Rufi, Rossberg, Rothenthurm, Monod, Rochette, La Paudèze.

Red Molasse.

Vevey, Ralligen, Wäggis, Horw.

MARINE MOLASSE.

I. TONGRIAN STAGE.

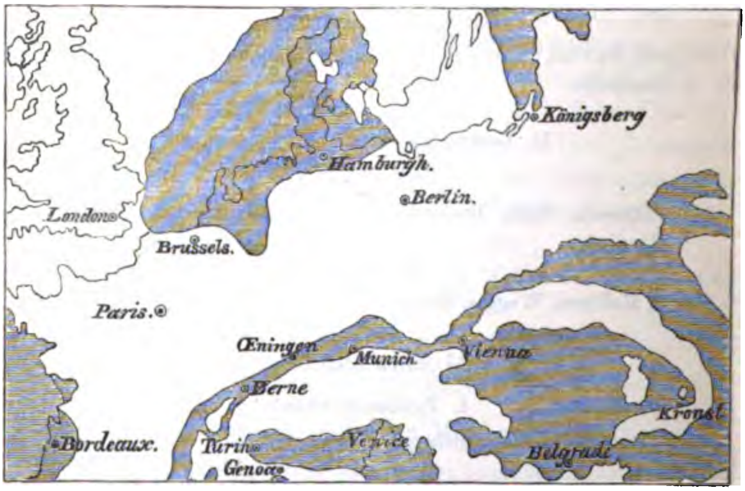
Basle, Porrentruy, and Delsberg.

Twice during the Miocene period the sea covered the Molasse district; and where rivers or brooks flowed into it, deltas were formed. One of these deltas occurs near Lucerne; and the alternation of marine and freshwater Molasse may be well observed in that locality. After the sea retreated, deep basins apparently remained along the Alps, and their salt water was gradually rendered fresh by the influx of streams; they then became converted into freshwater lakes, in which were deposited the conglomerates and sandstones which attain so remarkable a thickness on the shores of these inland seas. But the waters also spread sand and loam over the rest of the country, thus producing the materials of the freshwater Molasse.

We shall be better able to understand this alternation of sea and land during the Miocene period by a glance at the configuration of Europe at that epoch. Already (p. 284) we have noticed the distribution of land and sea in Eocene times, and shown that Europe was even then a considerable continent, traversed by numerous arms of the sea. A similar distribution appears to have prevailed during the Miocene period.

The following map (fig. 154) is intended to show the state of Central Europe at the time of the formation of the Helvetian marine stage. The Pennino-Carnic island, which then comprised the whole of the present Alpine region, had become larger from the addition of the Nummulitic and Flysch strata, which had been upheaved, and had probably at that time emerged along the Alps as dry land. In the west this island stretched to the south of France, and was then directly connected through Piedmont with the Italian peninsula. Towards the east it comprehended all the mountain country as far as the forty-fifth degree of longitude, and was then continued southwards through Dalmatia to Greece. To the north the Pennino-Carnic island was bounded by the sea, which formed the great basin covering the plain of Hungary, and then, narrowed to a strait, traversed the whole of Central Europe, and may be traced onwards through the valley of the Rhone to the Mediterranean. Further east,

Fig. 154.



Central Europe at the Middle Miocene period (the Helvetian stage).
The continents are white; the shaded parts represent the sea.

the Hungarian sea was connected with a great ocean, which spread over the south of Russia, and of which the Black Sea, the Caspian, and the sea of Aral are isolated remains. This Aralo-Pontic ocean probably stretched away east of the Ural Mountains, over the wide plains of Siberia, to join the Arctic Ocean, and thus separated Europe from Asia. Further south the same sea was connected with the eastern extremity of the Mediterranean, spreading over Armenia and Asia Minor, which is proved by the numerous marine Miocene fossils distributed throughout all these countries. But the Dardanelles were then closed, and even the Ægean sea did not exist. Greece extended over into Asia Minor as a continuous land area; and the islands of the Archipelago were the mountains of a land which became submerged at a later epoch.

If we look towards Africa we find that the Mediterranean covered Egypt, and was united to the Indian Ocean; the same sea also spread over Mesopotamia, and was probably directly connected with the Aralo-Pontic sea. As the flora and fauna of Morocco and Algeria agree in their principal characteristics, and have numerous species in common with those of the opposite European coasts, it has long been inferred that these countries were once connected by several isthmuses, as at Gibraltar, and by an extension of the land of Corsica and Sardinia, thus uniting Europe with the African coast. This supposition is confirmed by the bones recently discovered in Sicily, which show that the African elephant, the hippopotamus, and the spotted hyæna once dwelt in Sicily, and therefore that that island had, before the existing formation of land and sea, been connected with Africa.

Returning to the Miocene country, we see a vast continent to the north of the great strait which traversed Central Europe. Land stretched from Spain to Russia, occupying a great part of the Iberian peninsula, France, Germany, and Russia. What is now the Baltic was then probably dry land, and was connected with the primæval Scandinavia. In this region was the fatherland of amber, a product of Tertiary Coniferous trees. Denmark, Holland, and the north-east of Belgium were under water, and the sea extended as far as Cologne. Brittany, on the other hand, was probably united directly with

England, which is shown by the geological formation of the opposite coasts and the nature of the soil of that part of England. It is also probable that the British Islands then constituted only a slight portion of a great continent, which, stretching across the Atlantic Ocean, would have been united to America. In a later part of this work this hypothesis will be again considered.

In the south the Atlantic Ocean stretched into the Bay of Biscay, and covered the neighbourhood of Bordeaux. These localities are remarkable for the great abundance of their well-preserved marine animals of the Miocene period. The sea also penetrated deeply into the land at various parts of the coast of Spain and Portugal (as near Oporto, Lisbon, and Seville), and formed there marine sandstone rocks.

Such was the distribution of sea and land in Central Europe at the time when the marine Helvetian Miocene of Switzerland was deposited.

At the commencement of the Miocene period, in the Tongrian set of strata, the north of Europe was more depressed, and the sea spread over a larger area towards the north. In Eocene times the sea formed deposits in the Isle of Wight and in the Paris basin; and in the Tongrian period of the Miocene these districts were still marine shores. The sea also spread over Belgium and northern Germany, from which an arm extended through Cassel to Mayence, and through what is now the district of the Rhine to Basle, Porrentruy, and Delsberg, forming there the bay which has already been mentioned. In the next set of strata the sea disappeared from this region as well as from Alsace, from Hesse and Prussia, and from the Paris basin. But we still find a broad belt of sea running through Touraine, where we meet with the remains of former marine deposits, which, however, are not continued to the Helvetian stage.

In the Aquitanian period, probably in consequence of a gradual upheaval of the land, only a few basins of brackish water remained along the border of the Alpine region, although in Bavaria the sea still held its place. Consequently the whole of the great strait of the sea which, commencing at Vienna, traversed Central Europe had not retreated, but only the part which had overflowed Switzerland. At this period, therefore, the Pennino-Carnic island first came into direct connexion with the German continent situated to the north. This union was interrupted during the deposit of the Helvetian set of strata by a fresh irruption of the sea; but it was reestablished at the Œningian period, when the sea not only disappeared from Switzerland, but also from Bavaria; the basin of Vienna became covered with brackish water, whilst the plain of Hungary was under the sea and the Aralo-Pontic ocean still stretched over a wide region. We see, therefore, that the repeated alternation of marine and freshwater formations is connected with the rise and fall of the water in the long Central-European strait; and no doubt this was caused by the gradual depression and upheaval of the continent.

All that we know of the Swiss Miocene district in Tongrian times is, that its north-western boundary was washed by the sea, which extended beyond Basle into the region of St. Jacques and Dornach bridge, to Rädersdorf, Porrentruy, Delsberg, and the neighbourhood of the Brenets (in the Canton of Neuchâtel). Several fjords evidently penetrated into the country further to the south, showing us the phenomena of a shore-formation. The Jurassic limestone rocks which formed the shore are pierced by numerous holes of boring Mollusca, thus indicating the coast, which may be traced at many points, as near Cœuve, Miécourt, Develier, Delsberg, and Rädersdorf, and also near Brislach, Dornach, and Lörrach. These shores were inhabited by great herds of seals, which no doubt had many a battle with the large sharks in the neighbouring waters. Their teeth and bones, together with many trunks of trees brought down by streams, and fragments of the surrounding Jurassic limestone, were preserved in the mud of the shore, which has now become a calcareous sandstone. Here and there the mud has overwhelmed great numbers of oysters, which now form large banks imbedded in a yellow calcareous marl. Whilst the coarse rubbish remained lying close to the shore, the finer mud and sand spread over the middle of the bay, producing a fine-grained sandstone and blue marls. These form the lower beds of the ground on which the town of Basle is built.

In the following period we first of all meet with variegated marls, generally red, which spread over the low country between the Jura and the Alps, and were probably deposited in quiet fresh waters. These contain, apparently, a great quantity of salts of iron (perhaps derived from the Eocene pea-ore formation), which caused the variegated colours of the marls. The whole country was but little raised above the level of the sea; and in the deep depression along the Alps there was a lagoon of brackish water, as is shown in the neighbourhood of Lucerne (at Horw and Winkel) and near Ralligen on the Lake of Thun by a number of brackish-water animals. Moreover a brackish-water mollusk (*Cerithium margaritaceum*) has been found near Huttwyl (Berne), near Yverdun, near Belmont (in the valley of Paudèze), and at St. Sulpice near the Lake of Geneva, showing that in that period there still remained some pools of salt water.

The land seems at first to have had but a scanty covering of plants, as we find only a few species in the variegated marls, such as some palms, *Zizyphi* (jujube-trees), and some *Dryandræ*; but gradually there was developed an extremely rich and magnificent vegetation, which characterizes the second epoch of the Miocene strata. In the low grounds extensive peat-mosses were produced, surrounding lakes of various sizes. One of these peat-mosses stretched from Chexbres (in the neighbourhood of Vevey) to the Paudèze (near Lausanne); a brook discharged itself into the moss near Monod (in the vicinity of Chexbres), and conveyed to it great masses of mud and calcareous pebbles, which now enclose the remains of plants of that period. The northern border of the present Alpine region was probably washed by a great lake, occupying the basin which previously formed part of the sea. It was surrounded by peat-mosses, as we learn from the lignites of the Hohe-Rhonen and Rufi, which have been produced in these turbaries. Here and there the peat-mosses were overwhelmed by sand and rolled pebbles, which were also carried on as far as the lake. These deposits are greatly augmented in the third Miocene epoch, probably on account of a depression of the land having taken place. In the third set of Miocene strata the formation of lignite ceased, since it requires a period of tranquil development. In consequence of the sinking of the land the brooks which flowed from the interior acquired a greater fall; larger masses of pebbles were therefore conveyed to the basin; and thus a great quantity of materials was furnished for the formation of the conglomerate, which in part belongs to this period. The sea then again returned, first occupying the hollows of the land, gradually displacing the fresh water of the lakes, and finally spreading over the whole plain between the Jura and the Alps, and even penetrating into the valleys of the Jura, and by its breakers effecting the destruction of the rocks along the shores, and aiding in the production of masses of pebbles*.

The shell-sandstone beds along the Jura indicate the northern shore of this sea; they were produced by immense quantities of shells having been thrown up on the beach, broken to pieces by the surf, and mixed with sand. During this period the sea-bottom sank to its lowest point; and the depth of the depression may be approximately measured by the thickness of the marine deposits. Professor Studer estimates that the thickness of the marine Miocene strata on the Bütscheleck is at least 340 metres (about 1115 feet), and near the Martinsbruck, in the Canton of St. Gall, 700 metres (about 2296 feet). Now, although this thickness gives us no certain measure of the depression of the land at that time, since the ground was below the level of the sea, and the basins may have been filled with fresh water, there can be no doubt that the land must then have been at least 2800 feet lower than at present; for in the Canton of Berne the horizontal marine Miocene strata rise to this height, and they must have been under water at the time of that marine formation.

When the land began to rise again, the shallow parts were first laid dry: the sea retreated more and more from the Jurassic beach, but for a long time it formed a gulf along the deeper Alpine zone; so that the upper beds of the subalpine marine Miocene may be somewhat more recent than the shell-bed along the Jura. As the upper marine Miocene is not found either in the Canton of Vaud or near Geneva, whilst that formation occurs at La Chaux-de-Fonds and in various parts of the French Jura, it would appear that the Helvetian marine waters formed a junction with the arm of the sea in the lower valley of the Rhone by the way of La Chaux-de-Fonds, instead of by Geneva, which shows us how, in the Helvetian period, the configuration of that district differed from what it is at present.

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* Most of the pebbles of the conglomerate were probably rounded by the surf. We often see on the sea-shore enormous masses of pebbles very like those of the conglomerate. In Madeira the shore is covered in some parts with a thick bed of shingle, which is kept in constant motion by the surf; and the smooth pebbles of which it is composed are frequently driven far up on the land during storms.

Not only was the Helvetian sea displaced by the gradual upheaval of the land, but it became shallower by the great quantities of loam, sand, and gravel which were deposited in it, in some places producing deltas which stretched far into the water. As the sea gradually retreated, the rivers and brooks followed it; and these acted upon the half-hardened sandy masses which had emerged from the water, and spread them over the land in all directions. Thus began the formation of the upper freshwater Miocene strata.

Fresh water gradually took the place of salt water in the depressions of the land, and lakes and extensive marshes were formed, as in the Aquitanian period. Vegetation once more spread over the land as it became dry, and the country was by degrees covered with dense forests. Peat-mosses were formed in the marshy low grounds and on the banks of lakes; these were in some places covered up with sand and mud, and converted into lignites. Immense masses of sand and pebbles were carried by torrents of water over the plains of Eastern Switzerland. Some of these gravel-beds were probably deposited in a freshwater lake, which had taken the place of the former sea-gulf of the east of Switzerland, and had spread over the Upper Toggenburg and a great part of the Cantons of Zurich and Thurgau. The lake seems to have been rather shallow, and in many places was surrounded by peat, as evidenced by the brown-coal formation of the upper freshwater Miocene, which occurs near Käpfnach, in the neighbourhood of Wetzikon, on the Bachtel, in the upper valley of the Toss, near Elgg and Herderen, as well as in the vicinity of Wyl and Niederutzwyl.

These brown-coal deposits are covered with beds of sand and marl, which on the Albis attain a thickness of about 1000 feet. If these were formed in water, as seems probable from the seeds of *Chara* and the aquatic Mollusca which are found in them at Falletschen and Schwamendingen, the lignite-beds must have been covered with water, and the level of the lake must have risen considerably, in order to render the formation of these great deposits of sand possible. This rise in the lake was probably owing to the outlet of its waters being obstructed. At the time of the formation of the subalpine Miocene strata the Helvetian sea was connected with the eastern sea through Bavaria, and with the Mediterranean sea through France. The entire absence of the marine Helvetian Miocene in the vicinity of Basle and in Alsace proves that the sea did not stretch into that region, and therefore no outflow took place on that side. It is consequently very probable that at the period of the Upper Miocene the Swiss basin was directly connected with that of Bavaria, and that its waters flowed out in that direction. Now, if by any means the region through which this outflow took place was elevated, or the beds of the streams were filled up, the lake must have risen, and this rise of the water may have lasted for a considerable time. We can thus understand how the lignite-beds of the upper Swiss Miocene were gradually buried deeper and deeper under the deposit of sand, and that far above the lignite strata marshy soil has been here and there produced, and a large quantity of remains of plants of many kinds have been preserved in the marls and sandstones.

When the greater part of these Miocene beds were already formed, a volcanic eruption occurred near Œningen, and very likely occasioned the formation there of a basin which filled with water and became a lake. (A similarly formed basin may be seen in the chain of the Jura near Locle.) From the water flowing into it the lake deposited the white limestone which now occupies the bottom of the valley near Œningen. In the Vosges a river took its rise, the course of which may be traced by Belfort, Porrentruy, and Delsberg into the Canton of Soleure; in some places its current gave a sort of polish to the Jurassic rocks; and the river brought with it a great quantity of débris. The neighbourhood of Delsberg, especially in the Bois de Raube, is covered with pebbles, among which twenty-three different kinds of rocks from the Vosges mountains have been recognized. A tooth of a *Dinotherium* contained in this deposit tells us that it belongs to the fifth epoch of the Miocene. In the Sundgau, and as far as the environs of Basle, there are similar deposits of pebbles, probably derived from the Vosges, and showing that at that time the waters in this region flowed from north to south, and that the drainage of the Swiss Tertiary basin took place in quite a different direction from that which now prevails.

Of the Swiss Alpine region we can only say that it must have been more elevated than the Miocene country, as the sea of the Miocene period did not anywhere penetrate into the Alps.

In primæval times there was dry land in the direction of the Swiss central Alps. During the ensuing gradual continental upheaval this central land continually increased in size. To the north and south of the crystalline nucleus, the deposits of the Jurassic sea were first added to it, then those of the Cretaceous epoch, and afterwards the Eocene formations. By these means the land was not only enlarged, but the older parts of it became upheaved so as to attain a greater elevation. A similar remark may be made of the chain of the Jura. It must have been a range of mountains at the Miocene epoch, since the marine deposits of that period are only to be seen at its base. But the sea extended in separate fjords to Delsberg and La Chaux-de-Fonds, and during the latest period of the Miocene the waters flowed from the Vosges through Porrentruy and Delsberg into the Swiss basin; so that the configuration of the Jura must then have been very different from what it is at the present time.

The immense mass of conglomerate, and the occurrence in it of rocks not found in neighbouring localities, have much engaged the attention of Swiss geologists, and given rise to many hypotheses*. Messrs. Studer and Escher suppose that a series of hills, consisting of granite, porphyry, serpentine, and metamorphic schists, extended along the northern border of the Alps, something like the hill-country which runs along their southern boundary from Lugano to Ivrea. By the weathering of these hills (which sank during the subsequent upheaval of the Alps), and the violence of the breaking waters dashing over them, the pebbles forming the variegated conglomerate may have been produced.

The coarse gravel, says Studer, which the retreating surf left close to the shore, furnished the constituents for the conglomerate; and the firm sand and mud originated the Molasse and the marls. The existence of projecting tongues of land, of islands, and of Alpine torrents may explain the penetration of the conglomerate into the Emmenthal and Toggenburg. The granitic outlying hills may have been divided by a fissure running parallel to the border of the Alps; and as the sea-bottom gradually became deeper the ruins of the remaining rocky coast may have accumulated to a great thickness. Afterwards, in consequence of pressure from the interior of the Alps, the neighbouring limestone rocks were pushed laterally and covered over the shore-formation. The beds of conglomerate, broken by this pressure, became depressed, and the last remains of the granitic outlying hills were submerged, and when at the bottom of the water were covered by masses of limestone.

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* See Studer, 'Monograph of the Molasse,' p. 159, and 'Geology of Switzerland,' ii. p. 387. Leopold von Buch thought that the pebbles of the conglomerate had come out of the interior of the earth (Sitzungsber. Akad. Berlin, 1851, p. 12).

The foreign rocks of the variegated conglomerate of Switzerland cannot be derived from the Black Forest, as in that case the conglomerate of the Jura ought to contain them in much greater quantity than the conglomerate in the neighbourhood of the Alps, which is more distant from the Vosges; but the Alpine conglomerate possesses the largest quantity of them. We are therefore compelled to assume that the foreign rocks were derived from a chain of mountains which has now disappeared.

We have seen that the marine fauna during the Jurassic and Cretaceous epochs (see pp. 167, 186) was different in character in Eastern and Western Switzerland, and also that the nature of the rocks of the White Jura (p. 162) and of the Nummulitic rocks (p. 266) varies upon the line which Prof. Heer draws in imagination from Basle to the St. Gothard. The presence of the strait has been explained, which existed between the promontory of the Black Forest and the Alpine island (from the Wetterhorn to the Reuss); and if the mountains of the Black Forest be regarded as having, at some remote period, been extended as far as the vicinity of Napp, the phenomenon of the foreign rocks in the Swiss central conglomerate is explained.

At the Jurassic and Cretaceous epochs the lowlands of Switzerland were covered by the sea; but owing to the general upheaval of the land, which during the Aquitanian period drove the sea from these regions, they were laid dry and appeared as a mountainous country, the tops of the hills being covered with Triassic sandstones and Jurassic rocks. As the sea again gradually invaded Central Switzerland, the weathering and destruction of such a hill-country as this, which was exposed to the breakers, furnished those materials for the conglomerate which are foreign to the Swiss Alpine district; and hence the variegated conglomerate (Nagelfluh bigarré) has its maximum of development in the upper Emmenthal. This supposition explains the great resemblance of the stones in the conglomerate to those of the Black Forest, and the intermixture of Triassic sandstone and white Jurassic limestone. That streams flowed from the mountains into the low country is proved by the Alpine pebbles, which are by no means deficient, and which have especially formed a component part of the conglomerate chiefly accumulated in the neighbourhood of the Alps. Brooks and torrents flowed from all sides into the marine bay; and the sea of Eastern Switzerland probably received contributions from the Vorarlberg. Hence very diverse materials were brought together from all sides, the combination of which resulted in the Miocene or Molasse formation.

CHAPTER VIII.

MIOCENE FLORA.

I. *Number of Species of Miocene Plants.*

Switzerland takes the lead of all countries in its abundant deposits of Miocene plants. The Swiss flora in the Miocene period affords an insight into the vegetation which then clothed Central Europe; and the plants of the Tertiary formation are found to have a great analogy with the flora of the present day.

There are about eighty places in Switzerland where Miocene plants have been collected; the most important of these localities are enumerated in the following Table:—

Monod . . .	has	193	Miocene species.
Paudèze . . .	„	49	„
Environs of Lausanne .	„	96	„
Delsberg . .	„	32	„
Locle. . . .	„	140	„
Ralligen. . .	„	34	„
Eriz	„	68	„
Aarwangen . .	„	28	„
Hohe-Rhonen .	„	142	„
Albis and Irchel	„	60	„
Ruppen . . .	„	24	„
Schrotzburg .	„	78	„
Œningen . .	„	465	„

Prof. Heer is acquainted with 920 Miocene species of plants collected in Switzerland*. These plants are found in the Molasse or Miocene district, which occupies about one fifth of the area of the country.

Deposits of Miocene vegetable remains occur in the various localities just mentioned; but the size of each spot is of small extent, and the region generally is covered by a bed of sandstone, which conceals the Miocene organic world with a thick veil; and it is only little by little that rents can be made in the veil. The inconsiderable size of the field of observation must be borne in mind when the Miocene flora is compared with the living vegetable world of the present day, the extent of which we are familiar with. The Miocene flora thus compared is much richer than its modern successor.

According to Professor Heer, 747 species belonging to the Swiss Miocene flora may be thus subdivided:—

	291	are species of trees.
	242	,, ,, shrubs.
Total . .	533	species of woody plants.
	164	are herbaceous flowering plants.
	50	are cryptogamous plants.
Total . . .	747	

Woody plants form 76 per cent. of this number, and belong to 64 families.

Forests covered Switzerland at the Miocene period. An example of similar woody vegetation occurs in the valleys of the Orinoco and the Amazon in America, where the country is overspread with immense primæval forests.

The forms of insect life preserved in the Swiss Miocene strata afford evidence of an insect fauna mainly supported on wood in Switzerland, and thus confirm the predominence of forest vegetation.

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* Prof. Heer has described these species and given figures of them in his 'Swiss Tertiary Flora,' 3 vols., folio. Winterthur: Wurster and Co. 1855–1859.

The scanty occurrence of herbaceous plants in the Swiss Miocene may be explained by their fragility, and still more by the fact that they have no regular fall of the leaf. The majority of the herbaceous plants of the Swiss Miocene with which Prof. Heer is acquainted are aquatic and marsh plants, such as sedges, pondweeds, reed-maces, water-lilies, hydrocharids, &c., the leaves of which could easily deposit themselves in mud, whilst others have been transmitted to the present time by their fruits and capsules, which were carried by the wind into the water, such as many Compositæ, Lucerns, and Poranæ.

Of numerous plants there is indirect evidence through the presence of insects. Many insects are confined to particular kinds of plants, whose existence may be inferred from the fossil remains of the insects; for although the species of insects of the Miocene are distinct from those now living, they are frequently so nearly allied to them as to permit such comparisons and inferences. Thus a *Galeruca* found at Œningen (*G. Buchi*, Heer) enables us to assume that pondweeds existed there; and in the same way the presence of a forget-me-not is indicated by a small and elegant *Monanthia* (*M. Wollastoni*, Heer), that of brambles by a *Syromastes* (*S. coloratus*, Heer), that of nettles by a *Heterogaster* (*H. tristis*, Heer), that of a viper's bugloss (*Echium*) by a *Pachymerus* (*P. oblongus*, Heer), that of a species of trefoil by a *Clythra* (*C. Pandora*, Heer), that of thistles by a shield-beetle (*Cassida Hermione*, Heer), as well as by a *Glaphyrus*, and that of a figwort by a *Cionus*. Other insects give us intimation of flowery meadows; the *Syrphi*, *Anthomyæ*, and *Malachii* no doubt sunned themselves upon the flowers; and the bees and humble-bees of Œningen collected their nectar just like their relatives of the present day. The dung-beetles also announce the presence of grassy meadows. If we visit the cow-pastures on a summer evening a number of insects hum through the air, which during the day have remained concealed in the excrements of the cattle. Upon this food they live; but in the evening they swarm in the air in lively companies, and by the rustling of their wings break the stillness of the approaching night. If the cow-pastures should disappear in consequence of the cultivation of the fields, or of the spread of forests over the land, all these creatures would lose their accustomed aliment, and would no longer frequent the locality.

Coprophagous beetles existed at Œningen in forms very nearly allied to those now living, and chiefly resembling species which live in the excrements of ruminant quadrupeds. Hence, even before any Ruminants were discovered at Œningen, their occurrence could have been predicted; and we may further conclude from their appearance that there must have been grassy meadows in that region.

Professor Heer possesses a pretty complete series of the Miocene woody plants of Switzerland; and if we take the families belonging both to the Miocene and the existing floras which include woody plants, we may base a calculation upon these data.

There are 25 of such families, which comprise 152 species in the existing Swiss flora and 252 species in the Swiss Miocene flora.

If the flora of some particular Miocene locality be selected, it may be compared with that of a moderate-sized district of the present day; for instance, the flora of Œningen may be compared with that of the Canton of Zurich. Out of 422 Miocene flowering plants, Œningen has 136 species belonging to the 25 families also existing in the present flora. The Canton of Zurich now possesses, after deducting weeds and cultivated plants and the plants of the mountain-region, 894 species of flowering plants, 91 of which belong to these 25 families. Taking the proportion, 91 : 136 : : 894 : 1336, Œningen would have a total flora of about 1300 species of flowering plants. A similar result of about 1300 species of flowering plants is obtained for Œningen if the flora of the lowland district of the Canton of Glaris is made the basis of comparison. This flora consists of 812 species, 80 of which belong to the 25 families already mentioned. The proportion will be 80 : 136 : : 812 : about 1300.

Considering that the area from which Œningen received its flora is much smaller than either the Canton of Zurich or the lowland of Glaris, we may assume that Œningen must have possessed a flora at least twice as rich as that of any Swiss region of similar dimensions at the present time.

Comparing the existing flora found in the Miocene district of Switzerland with that of the Œningen stage, we obtain for the Œningen formation, by the method of calculation above given, about 2000 species. The existing flowering plants of the Miocene region (excluding Alpine plants and weeds) are comprised in 1280 species; and the 25 families belonging both to the Miocene and the existing floras include 104 of these; while there are 158 species in the Œningen stage out of a total of 505 flowering plants, the proportion being 104 : 158 : : 1280 : about 2000.

From Œningen we probably know only about one third, and from the whole of the Swiss Miocene only about one fourth, of the species of plants which then clothed Switzerland; so that there may have been at least 3000 species of flowering plants in the Swiss Miocene district.

Of the trees of the Swiss existing flora all the Conifers (with the exception of the Larch) have persistent leaves; all the leafy trees shed their leaves in autumn; and even among the shrubs of Switzerland there are only a few species (such as the holly, the ivy, and the mistletoe) of which the foliage remains through the winter. In Italy the region of evergreen leafy trees commences, including the laurel, the myrtle, and the evergreen oak; and evergreens constantly increase in importance towards the south, until in tropical and subtropical zones the trees change their leaves, as a general rule, quite gradually, so that they are never entirely deprived of their leafy adornment as is the case with the leafy trees of the temperate zone. In this respect the woody plants of the Swiss Miocene resemble those of the more southern zones; so that if we group together the trees and shrubs according to the analogy of their nearest allies among existing species, we obtain for the Swiss Miocene flora 327 trees and shrubs with evegreen foliage, and 206 with deciduous foliage.

II. *Numerical Proportions of the great divisions of the Vegetable Kingdom.*

In the Miocene flora the great groups of the vegetable kingdom were represented in very different proportions from those that prevailed in early periods, and especially before the Tertiary formation. In the Carboniferous flora the vascular Cryptogamia predominated, and exhibited peculiar and strange forms, which disappeared after that epoch. Throughout the early periods, the Cryptogamia, under a great variety of forms, continued to form an important part of the vegetable world. The Conifers and Cycads (Gymnosperms) came early, and attained their richest development in the Triassic and Jurassic periods, and were succeeded in late Cretaceous times by leafy trees, including Dicotyledons, which in Eocene times developed into a great number of families. In the Swiss Miocene flora the vascular Cryptogamia were represented by 50, and the Gymnosperms by 25 species—a much smaller number in proportion to the whole flora than in the periods before the Tertiary formation, but relatively much greater than in the flora of the present day. The existing Swiss flora possesses 55 vascular Cryptogamia and 11 Gymnosperms. The former now constitute about one fortieth, and the latter not more than one two-hundredth, of the existing Swiss vascular flora; while the vascular Cryptogamia were about one seventeenth, and the Gymnosperms about one thirty-fifth, of the Swiss Miocene flora. The great influence possessed by the vascular Cryptogamia (and especially the Ferns) and the Gymnosperms in the flora of the earlier ages of the earth's history was still active in the period of the Swiss Miocene, and caused in it the continuance of these types of plants.

The flowering or Phænogamous plants are divided into three principal natural classes—the Gymnosperms, Monocotyledons, and Dicotyledons; and the Dicotyledons are further subdivided into Apetalous, Gamopetalous [or Monopetalous], and Polypetalous plants. In the Swiss Miocene flora 25 species belong to the Gymnosperms, 119 to the Monocotyledons, and 592 to the Dicotyledons—namely, 189 Apetala, 84 Gamopetala, and 319 Polypetala*. In the existing German and Swiss flora the Apetala are represented by 185, the Gamopetala by 1010, and the Polypetala by 1168 species. Here, therefore, the proportion of these great divisions is about as 1 : 5½ : 6¼ ; whilst in the Swiss Miocene flora it is as 12 : 5¼ : 20, or nearly as 2⅕ : 1 : 4. The Polypetala include nearly four times as many species as the Gamopetala, and the Apetala more than twice as many.

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* The number of flowering plants described by Prof. Heer in his 'Tertiary Flora of Switzerland' is 806 species; but of these 70 are still very imperfectly known and doubtful; Prof. Heer has therefore left these out of consideration in the above as in the following revisions. Without them there are 736 Phænogamous plants, and in all 850 species, in Switzerland.

The Gamopetala in the existing flora of these regions are more than five times as numerous in species as the Apetala, and nearly approach the Polypetala. As we already know more species of Apetala belonging to the Swiss Miocene flora than of the Apetala which belong to the existing flora, it is clear that in the Miocene period these plants were far more numerous and more important in the vegetation of the country than they are at present. The Apetala occupy the lowest place in the classification of the Dicotyledons, and appear to have been much more numerous than the more highly organized forms adorned with corollas, the Gamopetala and Polypetala, in the Miocene flora.

The flowering plants (736 species) belong to 89 families, which gives an average of 8 species to each family. The average in the existing Swiss flora is 22·2. Hence the flora was relatively much more varied than at present, the species being constructed in accordance with a larger number of family types. A further evidence of this richness of the flora is to be found in the fact that it requires ten of the families containing the greatest number of species to make up half the Phænogamous species of plants. It is a general rule that the richer a flora in species, the more families must be numbered to represent one half of it. In the high northern regions this moiety is formed by 3–4 of the most numerous families, in Central Europe by 8–9, and in New Georgia, Carolina, and Java by 10. Consequently a proportion similar to that prevailing in those warm regions formerly existed in Switzerland.

The 10 most numerous families of the Swiss Miocene flora contain 363 species, viz. the Papilionaceæ with 117 species, the Cupuliferæ with 41, the Cyperaceæ with 39, the Laurineæ with 25, the Gramineæ with 25, the Rhamneæ with 25, the Salicineæ with 23, the Myriceæ with 23, the Proteaceæ with 23, and the Acerineæ with 22 species. Then follow families comprising, in each family, between 10 and 21 species—the Synantheræ, Celastrineæ, Moreæ, Juglandaceæ, Palms, Coniferæ, Mimoseæ, Naiadeæ, Ulmaceæ, Vaccinieæ, Sapindaceæ, Anacardiaceæ, and Xanthoxyleæ. These include 184 species, making, with the preceding 363 species, a total of 547 species; so that these 23 families constitute 75 per cent. of all the flowering plants.

The Papilionaceæ are therefore the most numerous family; and its species are found in the same proportions as in the tropical zones, where the first place is held by them.

Nowhere do the Cupuliferæ occupy so important a position as in the Swiss Miocene flora, of which they constitute 5½ per cent. With the Elms, Planes, Mulberries, Birches, and Myriceæ they form the order Amentaceæ (catkin-bearers), which, with the Salicineæ (willows), include 126 species in the Miocene flora of Switzerland, and form with the Papilionaceæ one third of the Phænogamous plants. Such a proportion is not found anywhere at the present day. In Germany and Switzerland the Cupuliferæ form 2·3 per cent.; and even in North America, where they are very numerous, they form only 3½ to 4½ per cent.

The families of the Gramineæ and Cyperaceæ (grasses and sedges), which together constitute the order Glumaceæ, took exactly the same share in the formation of the Swiss Miocene flora as they do at present in that of the temperate and warm zones, whilst the Laurineæ and Proteaceæ occupied quite a different position. The Proteaceæ are at present almost entirely confined to the southern hemisphere, occurring especially in Australia as numerous trees and shrubs. The laurels are widely distributed over the warm and torrid zones; but nowhere do they present so great a number of species. Their importance is increased by their abundance as individual trees. In the Miocene period they were the most widely distributed forest trees. In this respect they remind us of the Madeira and Canary Islands, which were formerly clad with evergreen forests of laurels, and still retain them in the interior of those islands.

Of the frutescent plants or shrubs, the Rhamneæ and Celastrineæ (forming the order Frangulaceæ) are most widely distributed: they include 54 species.

It is remarkable that the Labiatæ, Scrophularieæ, Ranunculaceæ, Caryophylleæ, Cruciferæ, and Rosaceæ are either entirely deficient or represented only by a few species in the remains of the flora which have come down to us, whilst these families contribute largely to the formation of the present flora of Switzerland. The absence or rarity of these forms in the Miocene deposits may be due to the herbaceous nature of the plants belonging to these families.

III. *Changes in the Flora during the Miocene period.*

In the preceding chapter it has been shown that the Miocene occupied a long series of ages for its formation, during which period the state of the ground underwent great modifications. The Miocene or Molasse was divided into five stages or sets of strata; and we may inquire, What changes, during this period, occurred in the vegetation of the Miocene? From the Tongrian, or lowest, stage of the Miocene in Switzerland we know but few plants; and they can furnish us with no information. A feather-palm and a fan-palm (*Phœnicites spectabilis* and *Sabal major*) and a species of cinnamon (*Cinnamomum lanceolatum*) have been found in the neighbourhood of Basle. the leaves of a *Podocarpus* (*P. eocenica,* Ung.) and a *Zizyphus* (*Zizyphus Ungeri,* Heer, fig. 195, in this work) were discovered some years ago (in 1864), in two different places, about half an hour's walk above Morgins in the Val d'Illiers (Valais), in a blackish-grey slate. These plants occur elsewhere in the Tongrian and in the lowest division of the Aquitanian stage; and they leave it undecided whether these slates, which very closely resemble those of Matt, are to be referred to the Tongrian or the Aquitanian stage. Of the flora of the fourth or Helvetian stage only a few species have been preserved*; but the plants of the second or Aquitanian stage, of the third or Grey Molasse, and of the fifth or Œningian stage, furnish us with abundant material for comparison. The following Table shows the number of species peculiar and common to these stages.

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* From the subalpine marine Molasse or Miocene Prof. Heer knows 24 species, of which 17 are from the quarries of St. Gall. The other species belonging to the fourth or Helvetian stage are from the marine molasse of the Canton of Vaud, and chiefly from a deposit above Lausanne, which forms the base of the shell-sandstone, and therefore certainly belongs to the oldest division of this stage. This may explain why the majority of these species (43 out of 72) are identical with those of the Grey Molasse of Lausanne. If we refer these species to the third stage, or Grey Molasse, an addition of 29 species would accrue to that set of strata, giving to it, in all, 79 peculiar species—120 in common with the second, and 92 in common with the fifth stage. The number of species belonging to the Helvetian or fourth stage would be reduced to 24. But as in that case 92 species would be common to

Stages.	Peculiar Species.		Common to the second stage.		Common to the third stage.		Common to the fourth stage.		Common to the fifth stage.	
	Species.	Per cent.	Species.	Per cent.	Species.	Per cent.	Species.	Per cent.	Species.	Per cent.
Second (Aquitanian) stage (with 336 species)	186	55	..	..	114	31	38	11	81	24
Third (Grey Molasse) stage (with 211 species)	58	27	114	54	..	..	50	23	87	41
Fourth (Helvetian) stage (with 92 species)	26	30	38	44	50	58	..	..	39	45
Fifth (Œningian), highest stage (with 566 species)	390	68	81	14	87	15	39	7		

In this Table it is manifest that 81 species of plants extend from the second or Aquitanian, and 87 from the third or Grey Molasse stage, up to the fifth or Œningian stage; and these species were spread over Switzerland during this long period.

Important changes in the vegetation of the country must have taken place during the formation of the Swiss Miocene; and their principal characteristics may be shown as follows:—

1. In general, without counting herbaceous plants, the evergreen trees and shrubs form about two thirds of the whole flora; but in the Upper Miocene the evergreens decrease relatively: thus in the Aquitanian or Lower Miocene (with 163 species) the evergreen trees constitute nearly three fourths, and in the

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the third and fifth stages, it cannot be doubted that these species also lived during the intervening fourth or Helvetian stage.

Œningian or Upper Miocene (with 166 species) they do not comprise much more than half the number of species. In the Œningian stage woody plants with deciduous leaves become much more numerous than in the Lower Miocene strata; in the fifth or Œningian stage they are represented by 154 species, whilst in the second or Aquitanian stage only 64 species of deciduous woody plants are found.

2. The Palms are by no means entirely deficient in the highest Miocene or Œningian stage, where fan-palms and a species of rotang occur; but they have become very rare, whilst in the lower freshwater Molasse they occupy an important position. Fig-trees and the fine-leaved Acacias are found in greater numbers in the lower freshwater Miocene, whilst maples and poplars acquire a greater importance in the Upper Miocene.

3. Australian and tropical forms of plants are less numerous in the Upper Miocene; their place is taken by Mediterranean and North-American forms of vegetation. In the second and third stages (the lower freshwater Miocene) there are almost exactly as many European as Asiatic types; but in the fifth or Œningian stage there is a predominance of one fourth of the European forms. The American types are at least twice as numerous as the Asiatic in all the Miocene stages. The typical forms, similar to those of the tropics, in the Swiss Miocene flora belong generally in equal parts to America and Asia. The American forms are twice as numerous as the Asiatic in the types belonging to the subtropical zone; the American forms are four times as numerous as the Asiatic in the types of species of the temperate zone. The tropical forms of the Miocene agree rather with Asiatic types, and the subtropical and temperate forms with types of the American temperate zone.

4. In the Swiss Miocene each stage has a considerable number of peculiar species, but only those can be regarded as characteristic which are widely distributed. We may indicate, as characteristic plants of the first and second stages of the lower freshwater Miocene, *Zizyphus Ungeri*, *Quercus furcinervis*, *Dryandra Schrankii*, and *Myrica hakeæfolia*: for the second and third or Lower Miocene stages we have the *Woodwardiæ*, the *Lygodiæ*, a large Sabal palm (*Sabal major*), a feather-palm (*Phœnicites spectabilis*), *Sequoia Langsdorfii*, and *Cinnamomum*

spectabile; for the fifth or Œningian stage a poplar (*Populus mutabilis*), two or three small-leaved elms, *Laurus princeps*, *Carpinus pyramidalis*, and the elegant *Podogoniæ*.

Of these characteristic plants of definite sections of the Swiss Miocene, the second or Aquitanian and the third or Grey Molasse stages have more in common than the other stages; and it may be asked whether it might not be desirable to unite the second and third stages. In this case the combined stage would have 438 species, a considerable number of which are characteristic of the lower freshwater Molasse. The flora of the Helvetian or fourth stage approaches that of the third or Grey Molasse stage rather than that of the fifth or Œningian stage, as most of the species that we know from the Helvetian belong to the oldest beds forming the transition to the grey Molasse. If we deduct these and take into consideration only the plants of the higher part of the Helvetian stage, the subalpine marine Miocene, 65 per cent. of its species are common to the Œningian or fifth stage. Consequently the greatest change in the Swiss flora of the Miocene took place during the fourth or marine Miocene stage—that is to say, during the period when the low grounds of that portion of Switzerland were covered by the sea.

IV. *Summary of Species.*

The distribution of the more important species of Miocene plants will now engage our attention. It is worthy of notice that many species of trees were spread over a great part of Europe in the Miocene period, and that the area of distribution of the trees and shrubs was larger during the Tertiary epoch than at present, from which we may infer a greater uniformity of climate in this quarter of the world. Among the most widely distributed Miocene trees may be mentioned *Sequoiæ, Taxodia, Glyptostroba*, camphor-trees, and tulip-trees, which were generally spread over the continent of Europe. Marsh- and water-plants are now remarkable for their wide diffusion. Miocene marsh-plants (the reed and the reed-mace of the Miocene epoch), like their living relatives, were spread over a great part of Europe.

In Miocene times numerous species of certain families and genera lived close together, whilst at present the analogous species are scattered all over the world. This is the case with the walnut-trees, poplars, maples, laurels, and some others. In the Miocene flora of Switzerland we frequently find all the types of a genus brought together, these types being now scattered in different parts of the world, and separated from each other by wide intervals, showing that they all probably issued originally from a common point, and formerly possessed a determinate area, which they left at a later period.

Of the 920 species belonging to the Swiss flora, 114 are cryptogamous or flowerless plants, and 806 are flowering plants. The former are divided into the two subclasses of the *Cellular* and *Vascular Cryptogamia.*

Fungi occupy the first rank as regards number of species. They are, for the most part, leaf-Fungi, living as parasites upon other plants, and producing dark spots and points upon their leaves and stems. The forty-two species described by Prof. Heer belong to 10 genera, and they are generally very nearly allied to living forms. They occur upon plants belonging to twenty-six different genera. The poplars and maples are each attacked by eight species of Fungi, the oaks by four, and the reeds by two species. Plants of these kinds are also invaded at the present day by numerous fungi; and we find that generally the species of fungi are analogous to their predecessors upon the corresponding trees.

The Swiss oak-leaves are now frequently covered with very small dot-like fungi (*Sphæria punctiformis*); and these dots or points resemble the *Sphæria interpungens,* Heer, which is found upon the oak-leaves at Œningen. Another similar fungus (*Sphæria ceuthocarpa*) produces on poplar-leaves large pale spots sprinkled over with black points, which are the fruits of the fungus; and the same parasite is found on the poplar-leaves of Œningen. A hard fungus (*Sclerotium populicola,* Heer) is still more frequent; and this can scarcely be distinguished from the *Sclerotium populinum,* Pers., which is extremely abundant upon dead poplar-leaves. A *Rhytisma* (*R. acerinum*) often covers the leaves of maples and sycamores, especially in the autumn; Prof. Heer found an extremely similar fungus on some fossil maple-leaves at the Hohe-Rhonen. Thus the relations between parasites and the plants which nourish them may be traced back to a very early period, and have continued through all the changes of the species of plants. On the other hand, a few peculiar types occur in the Miocene, such as a remarkable *Depazea* (*D. picta*) upon maple-leaves, and another species (*D. smilacis*, Heer) upon a sarsaparilla, which have not hitherto been found upon the corresponding living species.

Agarics in the Miocene period.—Only a single species (*Hydnum antiquum*, Heer) has been obtained from this tribe, to which mushrooms &c. belonged. That such fungi were abundant in the dark humid forests of Miocene times is shown by the numerous [mushroom-eating or] mycetophilous flies, the remains of which have been discovered. The fleshy fungi furnish nourishment to the larvæ of many species of gnats. Professor Heer frequently finds fungi full of white maggots, which afterwards transform themselves into winged insects. Small and delicate as these little creatures are, Prof. Heer has obtained from Œningen fifteen species of them, belonging to the genera *Mycetophila* and *Sciara*, with which are associated a number of fungus-eating beetles (*Scaphisoma*, *Scaphidium*, *Atomaria*, and *Oxyporus*), affording evidence of numerous forms of fungi in the Tertiary forests of Switzerland.

Charæ, with nine species, occupy the first rank among the Miocene Algæ. The two most abundant species are *Chara Meriani* and *Chara Escheri*, A. Br., which are distributed all over Switzerland; and their fruits, in countless thousands, sometimes fill the rocks. They must have covered the bottom of the waters with a green carpet like that produced in the present day by the *Chara vulgaris* and *Chara hispida*. Besides the fruits, the stems of several species, with their whorls of branches, have been preserved. Three species of delicate Confervæ have been preserved: two of these (*Confervites debilis* and *C. Nægelii*) form extremely fine branching lines upon the marly slabs of the Hohe-Rhonen, whilst the third (*C. œningensis*) presents whole tufts of long filaments. Similar Confervæ at the present day coat wells and springs with their green slime.

Mosses are exceedingly rare. Prof. Heer has distinguished three species, which probably belonged to the Hypnaceæ and lived in water.

Vascular Cryptogams are no longer of the same importance which they possessed in early periods of the world's history; yet in the Miocene formation they present several peculiar types different from those of the existing flora, but nearly in all cases belonging to living genera. There are fifty species, which belong to four orders—namely, Ferns, Marsileaceæ, Horsetails, and Lycopodiaceæ. The Lycopodiaceæ are represented at Œningen by two species of *Isoëtes* (*I. Braunii*, Ung., and *I. Scheuchzeri*, Heer), of which the former is very nearly allied to the living *I. lacustris*, Linn., a species which is distributed over Europe, Asia, and North America, forming a close green turf upon the sandy bottoms of lakes and pools. The Œningian species has a thick rootstock (rhizome), from which arises a tuft of leaves 6 inches long. It also flourished on a sandy bottom; for it occurs at Œningen only in a sandy stratum.

Equisetaceæ (horsetails) have, as representatives in Miocene times, five species, nearly approaching to existing forms. In Œningen there are two species (*Equisetum limosellum* and *E. limoselloides*, Heer), which represent the common *E. limosum* of the Swiss peat-mosses; another (*E. Braunii*, Ung.) resembles the rough horsetail (*E. hyemale*) of the Swiss river-banks; and others approach the common field and wood horsetails (*E. arvense* and *E. sylvaticum*). The Miocene species were of the same size, and possessed the same kind of sheaths as their living representatives; their fruits, as has been ascertained at least for two species, were collected into little cones; and their rootstock had oval knots arranged in whorls. One species from Locle, however (*E. procerum*, Heer), differs greatly from all living forms by its remarkably large stems (16 lines thick); this is the last representative of the gigantic forms of earlier epochs. With this, also, is associated a peculiar form (*Physagenia Parlatorii*, Heer) with an equally thick, jointed stem, and with whorls of bladders surrounding the nodes, which were embraced by an entire leafy sheath, pointed in front. This species, which was first discovered in Monod, and afterwards found in other localities, probably lived in water or mud, and the bladders served to keep it floating.

Ferns constitute the most numerously represented order of the vascular Cryptogams, the thirty-seven species of which, belonging to four families and eleven genera, form the greater part of the group of ferns in the Swiss Miocene flora. Exactly the same number of species are now living in Switzerland. A comparison of the Swiss Miocene ferns with the species of the present day shows some homologous species; but the general character of the Miocene fern-flora is quite different from that which now prevails in Switzerland, although nearly all the genera are still in existence. Two families, the Schizæaceæ and Hymenophylleæ, are not found in the existing Swiss flora; and even the Polypodiaceæ, which now, as in Miocene times, include the majority of the species, were generally at that period characterized by a special appearance. The Schizæaceæ are represented by five species of the remarkable genus *Lygodium*. These are climbing ferns with palmate or pinnatifid fronds, which bear fruit on a fringed margin. They live chiefly in Java; but one species occurs in Japan, and another in North America. The Swiss Miocene species are most nearly allied to the Javan. They lived principally at the Paudèze (near Lausanne), where both the fronds and the fruit of one species (*Lygodium Gaudini*, Heer) have been discovered. It is represented, together with the small-leaved *L. Laharpii*, in the right corner of the plate of "Lausanne in Miocene times" in the present work.

A bracken (*Pteris œningensis*, A. Br.), very nearly allied to the Swiss common species (*P. aquilina*), may be reckoned among the Miocene Polypodiaceæ. To the same tribe belong *Aspidium Filix antiqua*, A. Br., resembling the common *A. Filix mas*, and another (*Aspidium Escheri*, Heer), representing the marsh-fern (*A. thelypteris*, Sw.), whilst three other species find their nearest representatives in more southern forms (as *Pteris pinnæformis*, Heer, represented in *P. cretica*, Linn.).

Woodwardia Rœsneriana, Ung., sp., was a magnificent fern, with large feathery fronds, the pinnæ of which were deeply cleft and were 6 inches long. The elongated sori in this species stand in two rows in particular areas along the midribs of the lobes. This species was abundant at Eriz, and it has also been found at Monod and Rothenthurm. It is so nearly allied to the South-European and Canarian species (*W. radicans*, W.) that it may be regarded as the ancestor of the latter, and as having spread its beautiful plumy fronds in the primæval forests of

Switzerland, just as the living form does in the forests of Madeira, Teneriffe, Spain, and Southern Italy. A large *Lastræa* (*L. stiriaca*, Ung., sp.) was still more abundant; and this is the most widely distributed fern in the Miocene flora of Europe. It probably possessed a short woody stem, which bore a great crown of fronds (see figs. 164, 165). The fronds, which were about 3 feet long and 1 foot broad, were divided into long narrow pinnæ, traversed by a number of elegantly curved veins, on which the round sori were borne. Its nearest living ally, the *Lastræa prolifera*, Kaulf., sp., inhabits tropical America. The Swiss Miocene flora, however, possessed several very similar forms, such as *Lastræa polypodioides*, Heer (Rivaz), and *L. helvetica*, Heer (from Rivaz and the Hohe-Rhonen), which were also adorned with fine fronds, and find their nearest living relation in the above-mentioned American species. Altogether, 17 of the Swiss Miocene species of ferns may be designated as tropical forms, 8 have analogous species in Madeira and the Canary Islands, and 9 in Europe.

Osmunda Heerii, Gaud. (from Rivaz), is the only species in the Swiss Miocene flora of the family of Osmundaceæ. It is very nearly allied to the only European species, the royal flowering fern (*Osmunda regalis*) and to the North-American *Osmunda spectabilis*, W.

Marsileaceæ (or *Rhizocarpeæ*) constitute a very remarkable tribe of marsh- and water-plants, represented in the Swiss Miocene flora by a small *Pilularia* and two *Salviniæ*. Of the latter, which no doubt lived in the water, Prof. Heer has found one species (*S. formosa*, Heer) in the marls of the Schrotzburg. It has oval fronds with an elegant trellice-like venation, and is much larger than the only European species (*S. natans*, Linn.), vividly reminding us of the *Salvinia hispida*, Kth., from tropical America.

Cycadeæ, formerly so numerous, of the Gymnospermous subclass, are represented only by two species; and of these the fragments of stems and remains of leaves that have come down to our times are so imperfect that their determination cannot be regarded as certain.

Coniferæ are far more important, being represented by numerous species belonging to four families and nine genera. Of the

Gnetaceæ (or jointed firs) we have only a small shrub with naked, jointed, and striated twigs (*Ephedrites Sotzkianus*, Ung.), resembling the *Ephedræ* of the Mediterranean zone; and the Podocarpeæ also are represented only by a single species (*Podocarpus eocenica*, Ung.), which was probably, like its Chilian relative (*P. chilina*, Rich.), an evergreen tree with rigid, leathery, lance-shaped leaves. It has hitherto been observed here only in the lower division of the Aquitanian stage (near Ralligen on the Lake of Thun, and in the valley of Illiers).

Cupressineæ and *Abietineæ* are the two chief Coniferous families which, during the Miocene epoch, contributed largely to the composition of the forest-flora, not only in Switzerland, but all over Europe. In Switzerland there were 94 species of Cupressineæ and 17 species of Abietineæ. *Glyptostrobus europæus*, Br.,

Fig. 155.

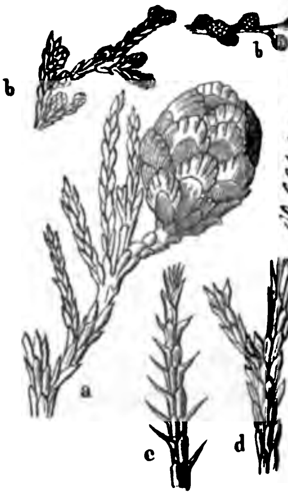


Fig. 156.

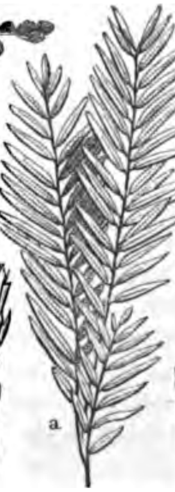


Fig. 158.

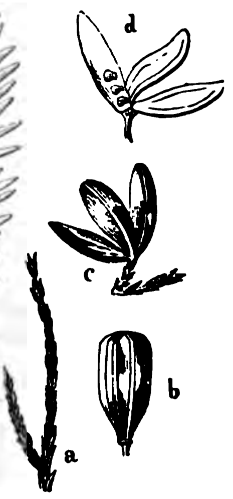


Fig. 155. *Glyptostrobus europæus*, Br., sp., from Œningen. *a*, branch with a mature cone; *b*, twig with male flowers; *c*, twig with divergent leaves; *d*, twig with adpressed leaves.

Fig. 156. *Taxodium distichum miocenum*. *a*, from the Hohe-Rhonen; *b*, male flowers, from Bilin.

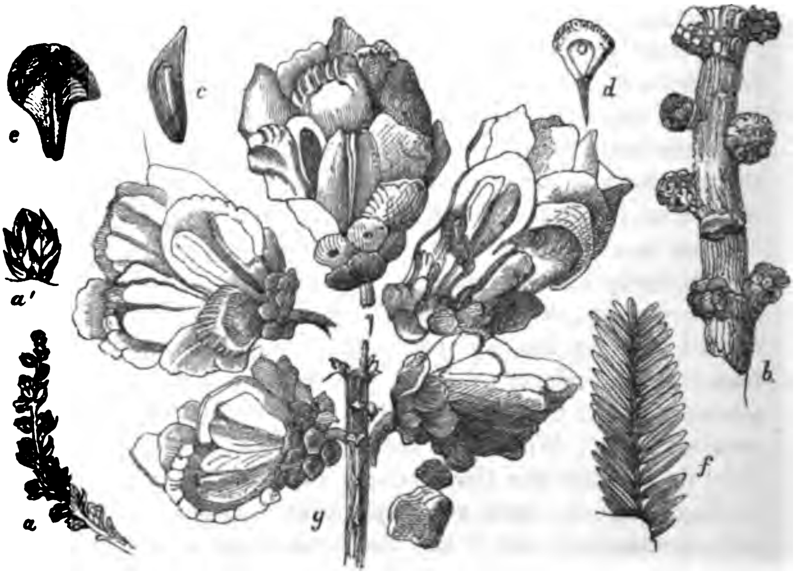
Fig. 158. *Widdringtonia helvetica*, Heer, from the Hohe-Rhonen. *a*, branch; *b*, closed cone; *c*, open cone; *d*, open cone with seeds.

predominates among the Cupressineæ. It was a tree with very closely approximated twigs covered with scale-like leaves, as in the ordinary cypress; but the leaves were alternate, and not opposite (as in the latter), and were at times divergent upon some of the twigs. The male flowers (fig. 155, *b*) were seated in small oval catkins at the extremities of the twigs; the female flowers lower down, in cones. The latter became converted into oval fruit-cones (fig. 155, *a*), the scales of which were furrowed in the back and notched at the margin. Prof. Heer has obtained some fine branches, flowers, and fruit from Œningen; and portions of the tree have been found at the Hohe-Rhonen, near Rufi, at Monod, at Rivaz, near Sensales, and at Locle; so that it was diffused over the whole of the Swiss Miocene region, forming densely bushy bluish-green trees like the *Glyptostrobus heterophyllus*, Br., sp., of Japan and China, which has probably been derived from the Tertiary species, and can only be distinguished from it by the scales of the cones—these having fewer notches at the margin, and being furnished on the back with a projecting recurved hook. Whilst this species is now confined to Eastern Asia, its ancestor (the *Glyptostrobus europæus*) spread over the whole of Europe; for it was as plentiful in Germany and Italy as in Switzerland, and it has also been found in Greece. Its area of distribution extended from 39° to 70° N. lat., as far as Greenland and Alaska.

Taxodium distichum miocenum, the swamp-cypress (figs. 156 and 157) had a still wider range. In Switzerland it is less abundant than the *Glyptostrobus*; but it has been obtained at six different localities in the upper and lower Miocene, and has been most frequently met with at Hohe-Rhonen. Prof. Heer has received it from many places in Germany and Italy; beautiful cones with seeds belonging to it have been found in the clays of Samland near Königsberg in Prussia (fig. 157, *a*); and it was equally common in the north of Greenland and Spitzbergen. From Spitzbergen Prof. Heer has received a great number of branches, scales, seeds, and male catkins (fig. 157). The species is also met with at Alaska, and at Orenburg in the Ural, and it probably lived in the countries between these distant localities. This species is completely analogous to the swamp-cypress of America (*Taxodium distichum*, Rich., sp.), a celebrated tree of

Mexico and the Southern United States. As in this species, the alternate leaves, traversed by a single rib and narrowed towards the base into a very short stalk, are arranged in two rows, by which these trees acquire a foliage resembling that of the yew, although in the latter the leaves are much more rigid and of a darker green colour. In the fossil, as in the recent species, the small male catkins (fig. 156, *b*, from Bilin; fig. 157, *a*, from Spitzbergen) are placed in considerable numbers along the twigs; and the woody fruit-cones are also similar in structure.

Fig. 157.



Taxodium distichum miocenum (swamp-cypress).

a, male catkins; *a'*, catkin enlarged; *b*, female flowers; *c*, seed; *d*, *e*, scales of the cone; *f*, branch. All these specimens are from Spitzbergen, 78° N. lat. *g*, cone from the Samland near Königsberg: most of the scales show their inner side, with the seeds.

The swamp-cypress has annual twigs, which it casts off every autumn, and is therefore bare during the winter. Of all trees, it pushes furthest into the soft mud of the swamps, forming in it an enormous network of roots. It thrives best where the soil is always completely saturated with water, as in the basins and bays on the banks of the Mississippi and in the small lakes in the midst of the immense marshes of Virginia and Carolina. When the trees become larger, they gradually sink in and fill up the water-basins by degrees, many of them still retaining their upright position, others lying one upon another in various directions, and covering the ground. Frequently whole groups of from 100 to 800 of such trees, from 40 to 70 feet in height, stand close together, and have been filling up the basins of their lake with organic materials, perhaps for a period of several thousand years. Sometimes the river breaks in upon them and undermines the soil, when the cypresses with their network of roots are floated away, forming those "snags" which are so dangerous to the steamboats on the Mississippi, and which, being carried down to the mouth of the river, are there accumulated in great masses, and form whole beds of wood in the mud. These are processes which throw much light upon the Marl and Brown-Coal formations of the Swiss Miocene country; for it is very interesting to find that the ancestors of the existing American swamp-cypresses were formerly spread over the whole of Europe as far as 78° N. lat., and that, like their American descendants, they probably increased and multiplied, and were carried down rivers and deposited in the sea.

Two other Cupressineæ of the Swiss Miocene land (*Widdringtonia helvetica*, Heer, and *Libocedrus salicornoides*, Ung., sp.) are of less importance, as they had a much narrower range: they belong, however, to two more genera, which are now quite foreign to Europe. *Libocedrus*, a genus characterized by its scale-like, adpressed, opposite leaves and flat jointed branches, is now represented only in California, Chili, and Australia; and *Widdringtonia*, with alternate scaly leaves adpressed to the branches, and cones composed of four scales (fig. 158), is now found only at the Cape of Good Hope and in Madagascar. These genera are trees resembling cypresses; the Chilian *Libocedrus* is distinguished for the excellence of its timber, which is an important article of commerce in its native country. The Swiss species (*Libocedrus salicornoides*, Ung., sp.) is nearly allied to the Chilian one and to the Californian *Libocedrus decurrens*.

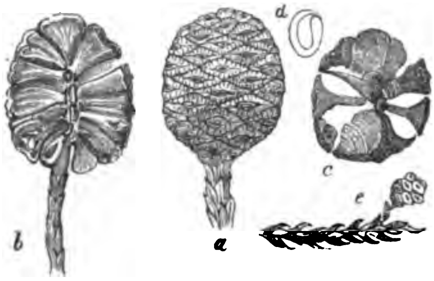
In Switzerland the *Libocedrus* has been found only at Monod, and even there in very imperfect fragments; but fine branches have been obtained at Radoboj. Of the *Widdringtonia* numerous branches, cones, and seeds occur at the Hohe-Rhonen.

The Cupressineæ of the Swiss Miocene present only exotic forms; and even the Abietineæ by no means resemble the Swiss native types. They constitute two genera, *Pinus* and *Sequoia*, the latter of which occurs at the present time exclusively in California, whilst the *Pinus* is spread over the whole northern hemisphere. The genus *Pinus* includes five groups—namely, firs, pines, pitch-pines, larches, and cedars. The last two are not found in the Swiss Miocene flora; the pines are represented by a species (*P. microsperma*, Heer) which agrees precisely in the small size of its seeds with the white American pine (*P. alba*, Linn.), but is quite different from the Swiss red pine. Of the pitch-pines, three species are indicated; but these are very imperfectly known; whilst of the firs we know eleven species, easily recognizable. In three of these species the leaves are grouped in threes—a character which now occurs only in the fir of the Canaries and in some American species. *Pinus tædæformis*, Ung., sp., from Lausanne, had the leaves 4–5 inches long, and in *P. saturni*, Ung., from Locle, which resembles the Mexican *P. patula*, the leaves were more than 6 inches in length. These long-leaved firs must therefore have been quite different in appearance from the firs of the present time. Two species belong to the same group as the American firs with five long thin leaves in each tuft (*P. strobus*); one species has therefore received the name of *Pinus palæostrobus*, Ett. It is one of the most abundant Conifers of the Miocene flora, and has left its long slender leaves in the Molasse of Ralligen, Monod, Hohe-Rhonen, Lausanne, and St. Gall. The five twin-leaved species also differ greatly from the common fir; and two of them (*Pinus hepios* and *P. Hampiana*) resemble American forms.

Sequoia, a genus allied to the pines, comprises the most important trees of the Tertiary forest. The distribution of the two Swiss species (*S. Langsdorfii*, Br., sp., and *S. Sternbergi*, Göpp., sp.) is very remarkable; for we find them from Central Italy and Greece up to the Arctic zone. Prof. Heer has received *Sequoia*

Langsdorfii (fig. 158 B) from the Rocky Mountains to the north-west of the United States, from Mackenzie River, and from Greenland in 70° N. lat.; it has also been found in Kamtschatka, at Alaska, at the Kuriles, and on the Kirghese steppes of Turkestan (in the vicinity of Orenburg). Thus it probably formed a zone round the whole earth in high northern latitudes; but it has also been found in many places in Central Europe. In Switzerland it occurs only in the Lower Miocene (most abundantly at Monod); but in Italy and Galicia it survived into the Œningian stage. *Sequoia Sternbergi* (figs. 160–163) is very rare in Switzerland: it occurs at Œningen; it has been discovered in many localities in Italy and Germany; and, singularly enough, it is one of the most abundant trees in the lignites of Iceland (called Surturbrand). From Iceland Professor Heer has seen leafy branches and cones; and the great trunks which lie buried in the ground in the northern part of the island and within the polar zone appear to belong to this species. Consequently, during the Miocene epoch, these two *Sequoiæ* were spread over an enormous area, while on the contrary the only two species now living are confined to a small spot of earth. One of them, the redwood (*Sequoia sempervirens*, Lamb., sp.), is so nearly allied to *S. Langsdorfii* that it must be regarded as

Fig. 158 B.



Sequoia Langsdorfii.

a, cone, from Rixhöft; *b*, longitudinal section with seed; *c*, transverse section; *d*, seed; *e*, female flowers. From Greenland, 70° N. lat.

a descendant of that species; and the other, the mammoth tree (*S. gigantea*, Lindl.), stands in the same relation to *S. Sternbergi*. In *S. Langsdorfii* and *S. sempervirens* we have rigid, leathery, linear leaves, narrowed towards the base and running down a little upon the branch, and arranged in two rows as in the yew; the small cones are composed of shield-like scales, enclosing several seeds with winged edges. In *S. Sternbergi* and *S. gigantea* the cones are much larger (as large as a hen's egg), and the leaves are arranged round the branches and adpressed to them at the base. The redwood (*S. sempervirens*) forms great

Fig. 159.

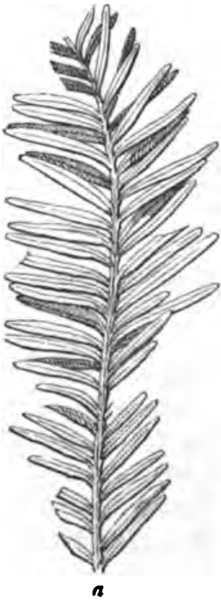


Fig. 159.

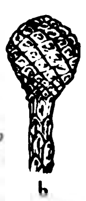


Fig. 159.

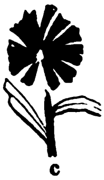


Fig. 161.

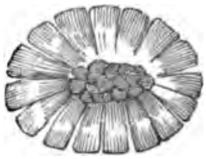
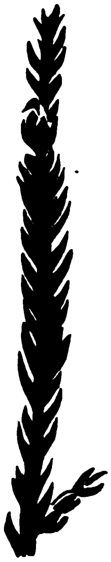


Fig. 162.



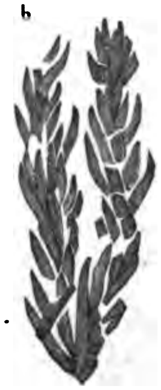


Fig. 160.

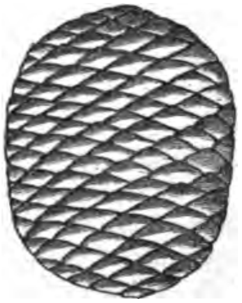


Fig. 163.

Fig. 159. *Sequoia Langsdorfii*, Br., sp. *a*, branch, from Monod; *b*, cone, from Salzhausen; *c*, section of a cone, from Monod.

Figs. 160–163. *Sequoia Sternbergi*. 160, twig, from the Surturbrand of Iceland; 161, transverse section of the cone, from Iceland; 162, twig, from Sotzka; 163, cone, from Chiavon, drawn from a plaster-cast of the original.

forests in the coast-regions of California, and throws up stems 250 feet high. The mammoth tree (*S. gigantea*) only occurs in the interior, and, as the most gigantic production of the vegetable kingdom, is one of the wonders of California. Some of these trees reach a height of 300–320 feet and a diameter of 20–30 feet. It comes down from an earlier period in the earth's history into our present world of plants, and is now confined to a narrow tract of country, whilst its ancestor was spread all over the world. As the mammoth tree, owing to the dense foliage of its branches, has a cypress-like appearance, very different from that of the redwood, it was at first placed in a distinct genus (*Wellingtonia*), until the structure of its cones and seeds showed its agreement with *Sequoia*.

Three other species of *Sequoia* fill up the gap between these extreme forms in the European Miocene flora (*S. sempervirens* and *S. Langsdorfii* on the one hand, and *S. gigantea* and *S. Sternbergi* on the other). These are:—1. *Sequoia Couttsiæ*, Heer, from England and Western France, which approaches *S. Sternbergi* in its foliage, and *S. sempervirens* and *Langsdorfii* in its cones and seeds, and occupies a middle place between these forms; 2. *S. Hardtii*, Endl., sp., which is intermediate between *S. Couttsiæ* and *S. Langsdorfii*; whilst a third species, *S. Ehrlichii*, Ung., approaches more nearly to *S. Sternbergi*, and a fourth and fifth (*S. Nordenskioldi*, from Spitzbergen, and *S. brevifolia*) are more nearly allied to the evergreen Sequoia. Thus we see that the genus *Sequoia*, in Tertiary times, was developed into a number of species and occupied a very prominent place. The intermediate forms have vanished, and only the two extremes have continued, under somewhat modified forms, into the existing flora. But the history of these remarkable mammoth trees may be traced still further back; for they most likely made their appearance as early as the Upper Cretaceous period. The tree described as *Sequoia Reichenbachi*, Gein., sp., mentioned at p. 231, was probably the precursor of the Tertiary species of *Sequoia*.

Monocotyledons, which are easily recognized by the parallel venation of their leaves, constitute between one fourth and one fifth of the number of species of flowering plants in the existing flora; in temperate and cold climates they clothe the meadows with their grasses, and the swamps and marshes with their rushes and sedges, whilst in the tropical world they take a large share in the formation of the forests with their majestic palm-trees, plantains, screw-pines, and dragon-trees. In the Swiss Miocene flora they probably formed an important part, although the species at present known to us constitute only about one sixth of the flowering plants. As at present, most of them belonged to the Glumaceæ, with 64 species—25 of these species being Gramineæ (grasses), and 39 Cyperaceæ (sedges).

Most of the grasses are known only by their leaves, stalks, and rootstocks, so that they cannot be accurately determined; but of some the flowers and seeds have been discovered; and among these a species of rice and four species of millet may be recognized. We most frequently meet with jointed reeds and broad sedge-like leaves. These belong to two species, one of which (*Arundo Gœpperti*) possesses solid rhizomes, and leaves with nearly equal longitudinal veins; whilst the other (*Phragmites œningensis*, A. Br., fig. 164, 6) has hollow rhizomes and leaves with some stronger veins, between each pair of which rise from two to seven more delicate veins. The *Arundo Gœpperti* is very like the Italian reed (*A. Donax*, Linn.), which is widely distributed in the Mediterranean zone, and is frequently brought into Switzerland for making fishing-rods and weavers' shuttles. The *Phragmites œningensis* resembles the common reed (*Phragmites communis*, Trin.) of the Swiss lakes and marshes, differing from it only by the somewhat broader leaves, which are not traversed by a middle vein stronger than the rest. The internodes of its rhizomes are long in soft, muddy, or swampy soil, but short in firmer or sandy ground; so that the length of these internodes enables us to infer the nature of the soil. As the rhizomes present long internodes both at Œningen and at the Paudèze, they inform us that in both localities the plants grew in soft muddy ground.

Cyperaceæ are chiefly known only by their leaves and stalks; but of several species we have the flowers and fruit, enabling us to recognize the genera *Carex*, *Juncus*, and *Cyperus*, which still form part of the Swiss flora. The *Cyperi*, however, are now rare in Switzerland; but several very large species are found, one of which (*C. Chavannesi*, Heer) is characterized by its fine large leaves, and another (*C. vetustus*, Heer, fig. 164, 7, p. 335) by its long slender spike-stalks, which probably formed a great umbel, as in the genus *Papyrus*.

Typhaceæ have similar grass-like leaves, and are divided into two genera, *Typha* and *Sparganium*, which are also in the present flora. The species are nearly allied to the existing ones; and just as the latter are now diffused over Europe, Asia, and America, their Tertiary relatives may also have been distributed over a great part of Europe. One species of reed-mace (*Typha latissima*, A. Br.) had thicker stalks and broader leaves than even the common species of the Swiss marshes (*T. latifolia*, Linn.); it was abundant at Œningen and the Hohe-Rhonen. The roof of the coal-pit at Greith, when Prof. Heer visited it, was closely covered with long brown ribbon-like bands produced by the leaves of this plant, indicating that the locality had been a marshy forest where this reed abounded. The burr-reeds (*Sparganiа*) also are not uncommon. Of one species (*Sparganium valdense*, Br.), which resembles the branched burr-reed (*S. ramosum*, Linn.) of the Swiss existing flora, the globular male flowers and the fruit have been found with the leafy stems at Monod.

Rushes no doubt lived in the Miocene marshes. Prof. Heer has obtained the flowers and fruit of three species, two of which are nearly identical with existing Swiss species.

Najadeæ are exclusively water-plants. Of the pondweeds seven species are known, one of which (*Potamogeton geniculatus*, A. Br.), with narrow grass-like leaves, resembles the small pondweed (*P. pusillus*) of the Swiss waters, whilst another (*P. Bruckmanni*, A. Br.) reminds Prof. Heer of *P. Hornemanni*.

The *Juncagineæ* are represented by a peculiar genus (*Laharpia*), which may be compared with the *Scheuchzeria* of the Swiss peat-mosses.

The *Hydrocharideæ* are represented by a plant like a *Stratiotes* and the *Hydrocharis orbiculata*, Heer, distinguished by its circular leaves, which no doubt floated on the surface of the water like the leaves of the water-lilies.

Of the *Irideæ* an entire plant, with leaves and a flower of one species (*Iris Escheræ*, Heer), has been obtained from Œningen; and of the exotic pine-apple family (*Bromeliaceæ*) a fine species

(*Puya Gaudini,* Heer) has been discovered at Lausanne. The latter resembled the arborescent *Puya* of Chili, and, like it, had a woody stem which bore a tuft of long spiny leaves. An equally exotic appearance is presented by the large leaves, traversed by numerous parallel lateral veins, of a species of ginger (*Zingiberites multinervis,* Heer) which has been discovered in the marls of the Rossberg.

Sarsaparillas (*Smilax*) predominate among the Liliaceæ. They are spinous evergreen climbing plants with round leaves, usually notched at the base so as to present a heart-shape. Prof. Heer has described eight species of this genus, of which one (*Smilax sagittifera,* Heer) has its nearest ally in the *Smilax aspera,* Linn., of Southern Europe; another (*S. orbicularis,* Heer) has a relationship to the *S. excelsa,* Linn., of Greece and Asia; and a third (*S. obtusangula,* Heer) is related to the Greek *S. alpini,* W.; whilst the other species more nearly resemble American forms. They were very well represented at Locle, where four species occur; but they are also met with at Œningen and in the neighbourhood of Lausanne. No doubt they lived as climbing shrubs in the forests, encircling the trees and bushes with green garlands.

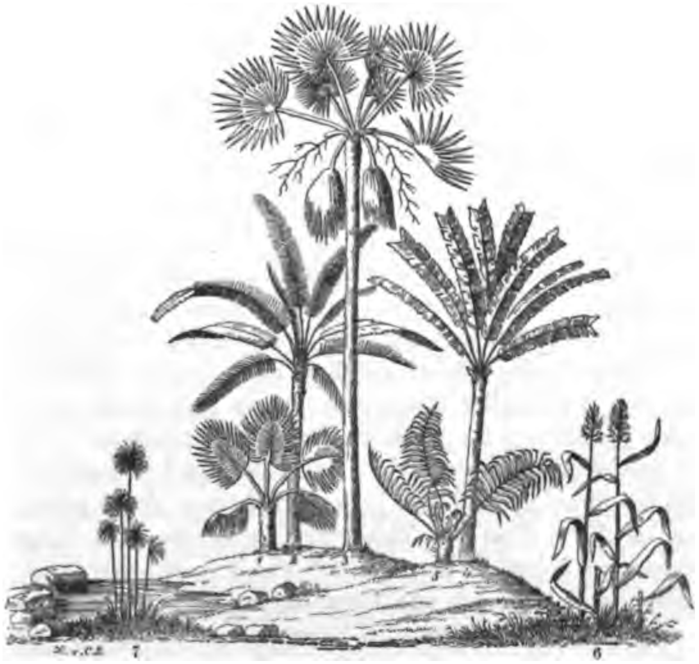
Palms constitute the most remarkable order of the Monocotyledons. Their generally simple columnar stems, adorned with a vast leafy crown, give them so peculiar an aspect that they are easily distinguished. As they belong exclusively to the warm and torrid zones, they appear in all tropical landscapes as the most characteristic trees.

Few of the Swiss Miocene fossils are so strikingly fitted as the palms to convince us that Switzerland was formerly clothed with plants of types which now belong to warmer zones.

Leaves of 11 species of palms, portions of the stems of 3 species, the spathe of one, and the flower of another species have been found in Switzerland. Prof. Heer has referred them to 15 species; but the three species founded solely upon the stems may perhaps be identical with three of those of which we know the leaves. This is especially probable in the case of *Palmacites helveticus,* Br., sp. This name is given to fragments of stems consisting of great clusters of long filiform vascular bundles, which occur not unfrequently in the lignite of Käpfnach near

Horgen. In the same place fragments of palm-bark and of a fan-like leaf have recently been discovered, belonging to *Sabal hæringiana*, Ung., sp.

Fig. 164.



Palms of Switzerland, restored from their leaves.

1. *Sabal major*, Ung., sp. 2. *Phœnicites spectabilis*, Ung. 3. *Flabellaria Ruminiana*, Heer. 4. *Manicaria formosa*, Heer. 5. *Lastræa stiriaca*, Ung., sp. 6. *Phragmites œningensis*, A. Br. 7. *Cyperus vetustus*, Heer.

Only a single indigenous species of palm, the dwarf fan-palm (*Chamærops humilis*, Linn.), is now found in Europe. According to the leaves, we may arrange the Swiss palms in two groups—namely, the *Fan-Palms*, with fan-like leaves, and the *Feather-Palms*, in which pinnæ, or lateral ribs, issue from a common long footstalk. The former group includes 7, and the latter 4 of the Swiss species.

Sabal major, Ung., sp., is the most abundant form of the fan-palms in the Miocene flora; it may be traced from Central Italy to Northern Germany (as far as 51° N. lat). In Switzerland it was most plentiful in the neighbourhood of Lausanne, where magnificent leaves have been collected. It resembles the shadow-palm (*Sabal umbraculifera*, Jacq., sp.) of the West Indies, except that its leaves do not attain so large a size. As in all species of *Sabal*, the long leaf-stalk is unarmed, and is continued at the apex into the fan; hence the rays of the leaf, which are folded at the base tike a fan, do not all issue from the same point, as they are attached to the lance-shaped prolongation of the leaf-stalk. This palm probably had a short stem crowned with a tuft of leaves, each of which was divided into about forty rays, and attained a length of about 2½ feet and a breadth of nearly 3 feet. Fig. 164, 1, and the fan-palms in the foreground of the plate of Lausanne in the Miocene period, are intended to give an idea of the appearance of this characteristic plant of the Swiss Miocene. Two other species (*Sabal Ziegleri*, Heer, and *S. hæringiana*, Ung., sp.) had smaller leaves, agreeing in this respect with the swamp palmetto of the southern States of North America; and, like that plant, they probably lived in swamps and marshes.

In the dwarf palm all the rays start from a single point, the apex of the leaf-stalk. This structure occurs in a fan-palm (*Chamærops helvetica*, Heer) which has been discovered in the sandstones of Bollingen and Utznach, and which therefore may be compared with the Southern European species of dwarf palm. With these palms are associated three other fan-palms of doubtful relationship, of which *Flabellaria Ruminiana*, Heer, is the most interesting. It must have had splendid leaves, some 6 or 7 feet broad, divided into about twenty-five flat rays, each traversed by three more strongly projecting longitudinal veins, all of which originated from the tip of the leaf-stalk. This palm appears to belong to the group of the Coryphineæ, and to be allied to the Indian genus *Copernicia*. It has been found in the tunnel of Lausanne and in the sandstone-quarries of Lucerne. Fig. 164, 3 and the slender fan-palm in the middle distance of the Lausanne Miocene landscape are intended to show the appearance of this tree. In a second species of *Flabellaria* (*F. latiloba*, Heer), found in the red marls of Vevey, all the leaf-rays are arranged round the apex of the leaf-stalk; but they widen very rapidly, and probably ten or twelve of them constituted the fan.

Of the feather-palms we find four well-defined species, belonging to an equal number of genera. Two of them Prof. Heer has endeavoured to restore from the remains of leaves which have been discovered at Lausanne and the Hohe-Rhonen. They are represented in the middle group of the Miocene landscape of Lausanne, and in fig. 164, 2&4. One of these species (*Phœnicites spectabilis,* Ung.) may be compared to the date-palm, but still better to the Piassava palm (*Attalea funifera*) of Brazil, a tree the fibres of which are now brought to Europe in great quantities for the fabrication of brushes and brooms. The Swiss Miocene species probably had leaves 10 feet long, from the thick midrib of which numerous long pinnæ 1–1½ inch in breadth, traversed by a median vein, were given off; and these were placed so close together as to cross each other at the margins. No doubt a great number of these large leaves were arranged in a crown at the summit of the cylindrical stem. In the second species (*Manicaria formosa,* Heer, fig. 164, 4) the pinnæ of the leaves were united so as to form a great undivided surface, which would probably be torn here and there by the wind, as is so frequently the case in the *Manicaria saccifera,* Clus., sp., and in the plantains and bananas. The *Manicaria* has a lofty trunk, which bears a crown of immense erect leaves; and the Swiss species must have had a similar ornamental appearance.

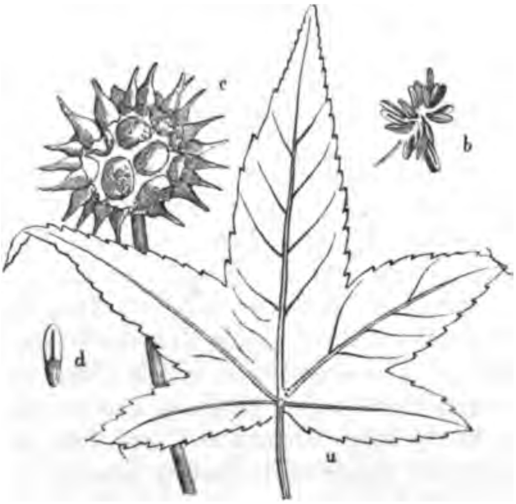
Geonoma Steigeri, Heer, from the sandstone-quarries of Büron (Canton of Lucerne), was probably a very much smaller species. The pinnæ, which are very broad at the base, are pointed at the end, and traversed by veins which converge towards the apex, just in the same way as in the *Geonomæ,* small palms found in the virgin forests of tropical America.

Calamopsis Bredana, Heer, the fourth species of the feather-palms, belongs to the group of the Rotangs or Canes, the enormously long climbing stems of which give them a characteristic appearance. Of this species Prof. Heer has obtained beautiful fragments of leaves from Œningen. Long narrow pinnæ issue in pairs from the thick midrib: the pinnæ are traversed by about ten or twelve longitudinal ribs, between which five or six fine intermediate veins are seen. This structure of the leaves closely resembles that of the living Rotangs of tropical Asia; and a fine spathe, a foot long, which has been sent from Œningen to Prof. Heer, and which certainly belonged to a palm, confirms this analogy. Neither the leaves nor the spathe had any spines; and in this respect the *Calamopsis Bredani* differs from the living species, in which these organs are thickly armed with spines.

Dicotyledons form the great mass of the Tertiary plants, which causes the flora of the Tertiary period to approach nearer to that of the present day than to the Cretaceous flora, although the Tertiary flora is distinguished from the existing flora by the great abundance of the apetalous trees. Among these we meet with families which are now quite foreign to Europe, such as the Balsamifluæ (Liquidambars), Plataneæ (Planes), Artocarpeæ (bread-fruit trees), Nyctagineæ, and Proteaceæ; whilst other groups are represented by a much larger number of species, such as the Cupuliferæ, Myriceæ, Ulmaceæ, Ficaceæ, and Laurineæ. There are not many representatives of the family of the willows (Salicineæ) in the Miocene formation of Switzerland.

Four species of Balsamifluæ or Liquidambars belong to the existing flora—one living in North America, a second very similar species in western Asia, a third in India, and a fourth in China. The two Swiss Miocene species resemble the North-American tree (*Liquidambar styracifluum*, Linn.), which yields Liquidambar balsam containing a tolerable quantity of benzoic acid; and one of the Swiss species (*L. europæum*, A. Br.) is so nearly allied to this North-American tree that it is probably to be regarded only as a variety. Its leaves, which have long petioles (fig. 165, *a*), are divided into from three to five lobes, which are regularly and sharply toothed and produced into small points. The fruits, each of which is drawn out into a pointed beak (fig. 165, *c*), are collected into a rounded capitulum, and enclose winged seeds (fig. 165, *d*). Near one leaf there is a clump of anthers (fig. 165, *b*), probably derived from the male flowers of this tree. It probably attained a considerable size, and had the appearance of a maple. It lived not only in Switzerland, but also in Italy and Germany, and it has even been found in Greenland (in 70° N. lat.).

Fig. 165.



Liquidambar europæum, A. Br., from Œningen.
a, leaf; *b*, male flowers; *c*, fruit; *d*, seed, from Schrotzburg.

The plane tree (***Platanus aceroides***, Gœpp.) of the Tertiary formation spread from Central Italy to Iceland, Greenland, and Spitzbergen, occupying an area of 40 degrees of longitude and 33 degrees of latitude. The marls of Schrotzburg (near Œningen) have preserved all the organs of this tree—the finely striated bark, beautiful leaves of many forms, the male catkins, and the fruits, some of the fruit being in an isolated state and furnished with its circlet of hairs, and others being united into globular capitula. This plane is most nearly allied to the American species (***Platanus occidentalis***, Linn.), from which it cannot be distinguished by its leaves; but the fruits, which are not swelled into the form of a club, furnish a clear distinction between them. It is remarkable that plane-leaves occur in great quantities in the ravine of Schrotzburg; whilst at Œningen, only half an hour's walk from that valley, merely a few fruits have been discovered. Probably a plane-forest grew in the neighbourhood of the Schrotzburg, from which the fruits were carried by the wind to Œningen.

Salicineæ are represented by the same two genera as at present; but whilst in the existing flora of Central Europe there are twelve times as many willows as poplars, in the Swiss Tertiary flora the poplars nearly equal the willows in number. Among the willows those types are wanting which now predominate in the Swiss thickets of mountain and valley, such as the osiers, the black and purple willows, and all the Alpine willows; the species belong for the most part, like the few willows of warm zones, to the groups of the arborescent brittle and amygdaline willows. The most abundant species are *Salix varians*, Gœpp., and *S. Lavateri*, A. Br., of which we know, besides the leaves, the fruit-spikes and male catkins. They were willows with long, narrow, serrated leaves like the brittle willow (*S. fragilis*, Linn.). The large-leaved willow (*Salix macrophylla*, Heer) had leaves about a foot long and 2 inches broad; it has been found at the Hohe-Rhonen and near Eriz, and is most nearly allied to the willow of the Canary Islands.

Only four wild poplars now exist in Switzerland; but eight species have already been found in the Miocene sandstone-rocks and marls. They belong to four groups, namely:—first, the *Aspens*, with deeply slit bracts covered with long hair, and coarsely serrated leaves with stout lateral main veins strongly bent forwards; secondly, the *Black Poplars*, the leaves of which are not longer than broad, and are furnished with bordered serrations, while their bracts are naked or but slightly hairy; third, the *Balsam-Poplars*, with the leaves longer than broad, cordate, or elongate-ovate or elliptical, with the serrations not bordered; and, fourth, the *Leather Poplars*, with coriaceous and often entire leaves and the fruit generally three-valved. The leather poplars occur at present only in Asia, and the balsam-poplars in America and Asia, while the aspens and black poplars are found in Europe, Asia, and America. In Tertiary times these types, which are now scattered over different parts of the world, were associated together in Switzerland. The aspens were rare, and were only represented by one species (*Populus heliadum*, Ung.); but the others were more abundant. To the black poplars belongs the

Populus latior, A. Br., which very closely resembles the American species *P. monilifera* and *angulata,* Ait.; it is one of the commonest trees at Œningen, and is also found near the Schrotzburg, in the Miocene of the Canton of Thurgovia, at Kirchberg in the Toggenburg, at the Ruppen, and in the limestone of Locle. Of this tree Prof. Heer possesses fine leafy branches, buds, flowers, and fruit. The long-stalked serrated leaves are sometimes of very considerable size. *Populus melanaria,* Heer (from Wangen and Lausanne), was much less common; it resembled, in the form of its leaves, the common black poplar. The *Populus balsamoides,* Gœpp., is very nearly allied to the American balsam-poplar; it was widely distributed in the Swiss Miocene. Its large cordate or oval-elliptical, serrated leaves are among the most abundant fossils in the sandstones of Lausanne, the Albis,

Fig. 169.

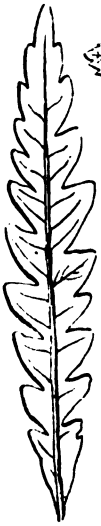


Fig. 167.

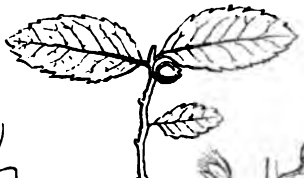
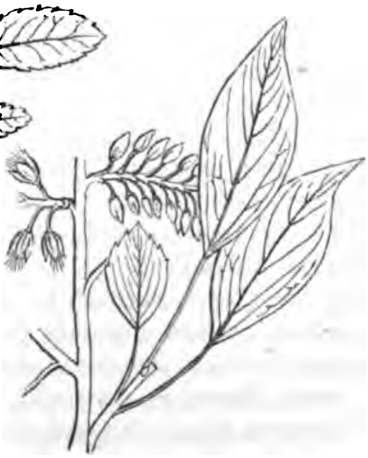


Fig. 166.



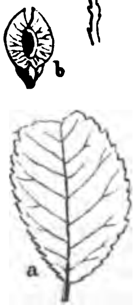


Fig. 168.

Fig. 166. *Populus mutabilis,* Heer, from Œningen, ½ nat. size.
Fig. 167. *Planera Ungeri,* Ett., a branch with fruit, from Œningen.
Fig. 168. *Ulmus Braunii,* Heer, from Œningen. *a,* leaf; *b,* fruit.
Fig. 169. *Myrica œningensis,* A. Br., sp.

and Irchel. Like its American relative, it was no doubt a large tree with splendid foliage. The leather poplars constitute a peculiar oriental group of tall bushes with leathery evergreen leaves. On the same branch the lower leaves are toothed, whilst higher up the leaves are entire and elongated (fig. 166). One species (*P. mutabilis*, Heer) occurs in Switzerland only in the upper freshwater Miocene, whilst the other (the nearly allied *P. Gaudini*, Fisch.) is found in the lower Miocene of Lausanne. The former is one of the most abundant plants at Œningen; Professor Heer possesses its flowers and fruits and fine leafy branches. He has a slab, measuring a foot in height by a foot and a half in width, on which a ramified leafy branch is as beautifully spread as if it had been specially prepared for its primæval herbarium. This species is so near the only known living species of leather poplar (*P. euphratica*, Ol., of which the *P. diversifolia*, Schr., is merely a variety) that it may be unhesitatingly regarded as its ancestor. The only differences are that the living species does not possess the large form of leaves, that its fruits are larger, and the rhachis of the spikes thinner; and it is doubtful whether such characters are sufficient to constitute it a separate species. *Populus euphratica* grows along the rivers of Mesopotamia, in Kurdistan, Songorei, and Khiva, and also on the banks of the Jordan near Jericho, where it forms bushes about 8 feet high.

Amentaceæ are represented in the Swiss Tertiary flora by ninety species, belonging to seven families, of which the Cupuliferæ occupy the most prominent position. With the exception of the beech (*Fagus*) we meet with all the genera of this order in the European flora—*Carpinus, Ostrya, Corylus,* and *Quercus.* The first three genera are rare, although a species of hornbeam (*Carpinus grandis*, Ung.) and a hazel (*Corylus MacQuarrii*, E. Forbes, sp., *C. grossedentata*, Heer) were widely distributed over a great part of the known Tertiary land.

The oaks are of far more importance. They occur in a wonderful abundance of species, of which, however, none appear in great quantities. The thirty-five species that Prof. Heer has described are almost without exception oaks with leathery leaves, sometimes entire, sometimes toothed and even spined on the margins, such as now occur in American and in Mediterranean countries. Of the 20 species which can be compared with those now living, 13 may be characterized as American, 5 as Mediterranean, and 2 as Persian forms. The first, resembling American species, are not only the richest in forms, but also the most widely distributed. Among them we find:—species with long lanceolate leaves with entire margins (such as *Quercus neriifolia*, A. Br.), like the willow-leaved *Quercus phellos*, Linn.; others with strongly toothed leaves (such as the widely distributed *Q. furcinervis*, Rossm., sp., *Q. lonchitis*, Ung., and *Q. Drymeia*, Ung.), which resemble Mexican forms (*Q. Sartori*, Liebm., and *Q. lancifolia*, Schl.); and others, again, the leaves of which are divided into large lobes, as in *Q. falcata*, Mich., the lobes being either blunt (*Q. Buchii*, Web.) or acute (*Q. cruciata*, A. Br.). The species which resemble Mediterranean forms (*Q. sclerophyllina*, Heer, *Q. mediterranea*, Ung., and *Q. Hagenbachi*, Heer) have rigid, leathery, sharply dentate leaves, like *Q. coccifera*, Linn., *Q. pseudococcifera*, Desf., and *Q. fruticosa*, Brot.

Oak-forests of the Swiss Miocene land must have had a different appearance from those of the present time on the northern side of the Alps. Alders and birches, however, probably fringed the brooks and rivers, trees similar to those which we now see, although we cannot place the nine Swiss Miocene species side by side with any very nearly allied indigenous living forms. The most abundant of the alders is the small-leaved *Alnus gracilis*, Ung. *A. Kefersteini*, Gœpp., sp., which is widely spread in Germany, is very rare in Switzerland. The latter species occurs in Italy (in Tuscany), and is found as far north as Iceland, Kamtschatka, and Alaska. One of the birches (*Betula Dryadum*, Br.) had an equally extensive area of distribution; but in Switzerland it is found only in the Upper Miocene; whilst another species (*B. Brongniarti*, Ett.) occurs only in the Lower Miocene.

Ulmaceæ at the present day are only represented in Central Europe by the genus *Ulmus*; but in Miocene times it was associated with *Planera*, the existing species of which occur in the south of the Caucasus, in Crete, and in North America. The fossil species (*Planera Ungeri*, Ett., fig. 167) is most nearly allied to the Caucasian *Pl. Richardi*, Mich., and is scarcely distinguishable from it by the leaves; but the fruits are smaller and less wrinkled. This tree is distributed through all the stages of the Swiss Miocene, and it probably formed woods in moist low grounds and on the banks of rivers, like its living relative among the mountains of the Caucasus. It had a very wide area of distribution; for its known southern limit is in Central Italy (Sinigaglia), whilst it extends northward as far as Greenland; its eastern boundary is near Tokay in Hungary, and its western in the Canton of Vaud. The true elms are much rarer. *Ulmus minuta,* Gœpp., is characterized by its elegant little leaves, and is allied to the Asiatic *U. parvifolia,* Jacq. The *Ulmus Braunii,* Heer (fig. 168), closely resembles *U. ciliata,* Ehrb., in its leaves and fruit. The elms are confined to the Upper Miocene (at Œningen, Schrotzburg, and Locle).

Myriceæ (twenty-three species) probably formed dense copses, partly evergreen, in the swamps and marshes. *Myrica œningensis,* A. Br., sp. (fig. 169), had elegant deeply lobed leaves, closely resembling those of *M. asplenifolia,* Br., a small American shrub with leaves like the fronds of certain ferns; *Myrica Studeri,* Heer, reminds us of the waxberry (*Myrica cerifera,* Linn.), from the fruits of which a sweet-smelling wax is perpared; *M. deperdita,* Ung., resembles the Pennsylvanian *Myrica*; whilst *M. Ungeri* and *M. Græffii,* Heer, which have rigid deeply lobed leaves, have their nearest ally in *M. serrata,* Lam., from the Cape of Good Hope.

Fig-trees are remarkable for the number of their species. The Swiss Miocene has 17 species, 12 of which occur in the second stage, 6 in the third, 2 in the fourth, and 5 in the Œningian stage. Thus they belong especially to the older Swiss Miocene. Among these numerous species we find no forms representing the European fig-tree (*Ficus carica,* Linn.). All the Swiss Tertiary species had undivided, leathery, and no doubt evergreen leaves, most resembling in form those of Indian and American species. The cylindrical and generally long petioles, the leaves frequently inequilateral at the base, the lateral veins which often form curves running parallel to the margin, the small tubercles with which the leaves are covered, the two opposite first lateral veins running forward at an acute angle (which occur in many penninervian leaves), are all characters which facilitate the recognition of these fig-leaves.

Indian types of the Swiss Miocene flora are found in the *Ficus appendiculata,* Heer, the leaves of which have nearly the same form as those of the banyan (*Ficus religiosa,* Linn.); the *Ficus arcinervis,* Rossm., which very closely resembles *F. cuspidata,* W.; and the *F. multinervis,* Heer, the leaves of which agree with those of the India-rubber tree (*F. elastica,* Linn.) in their form and in the close arrangement of the parallel lateral veins. But the most abundant and widely distributed of the Swiss species belong to American types, such as the long-leaved *Ficus lanceolata,* Heer, which extends from the Lower to the Upper Miocene, and occurs also in Germany and Italy, and the lime-leaved fig (*F. tiliæfolia,* A. Br., sp.), the magnificent cordate inequilateral leaves of which are among the principal ornaments of the Œningian flora. This is the most abundant tree in the lignite marls of Elgg, where its large leaves lie in masses one over the other; but it likewise occurs in the Lower Miocene, and was spread over a great part of Europe from Italy to the Baltic. The numerous fig-trees must have given a southern character to the Swiss Tertiary forests.

Laurineæ were even more numerous than fig-trees. Prof. Heer has described twenty-five species of Laurineæ from Switzerland. They are of the more importance as they were among the most abundant trees of the period, and formed a chief part of the Tertiary forests. The two principal genera are *Laurus* and *Cinnamomum.* The species of both have leathery, shining-green leaves, which are penninervate in the true laurels, whilst in the cinnamons two lateral veins originate from the midrib, a little way from the base of the leaf, and run towards its apex, which they sometimes reach, but sometimes only extend to the middle of the leaf: the leaf is thus three-veined. The flowers of these trees are small, tetramerous in *Laurus,* trimerous in *Cinnamomum;* the fruits are one-seeded berries, surrounded at the base by the calyx.

Of these genera of Laurineæ, Prof. Heer has obtained not only beautiful leaves and leafy branches, but also the flowers and fruit, and even flowering branches still bearing their leaves (fig. 170, 171). The two most important species are the Tertiary camphor-tree (*Cinnamomum polymorphum,* A. Br., sp.) and Scheuchzer's cinnamon-tree (*C. Scheuchzeri,* Heer), represented in figs. 170 & 171. The latter species has been found at forty and the former at fifty different places in Switzerland; they are consequently among the most abundant fossils of the Swiss Miocene, and may be regarded as essentially characteristic trees of the Miocene epoch. They make their appearance in the first or Tongrian stage, and extend up into the Œningian or most recent stage. They are distributed over Italy, Germany,

Fig. 171.

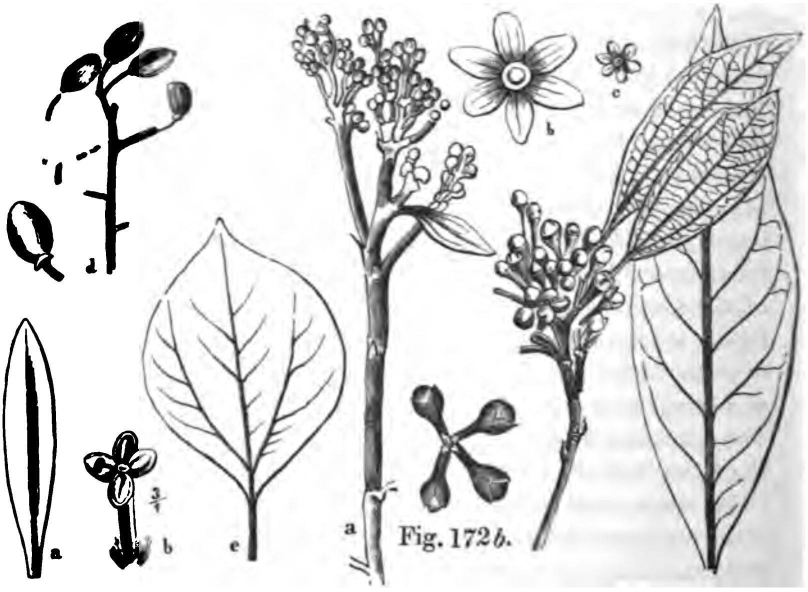


Fig. 173. Fig. 170. Fig. 172.

Fig. 170. *Cinnamomum Scheuchzeri*, Heer, a flowering branch from Œningen.
Fig. 171. *Cinnamomum polymorphum*, A. Br., sp., from Œningen. *a*, branch with flower-buds; *b*, flower, enlarged; *c*, of the natural size; *d*, fruit; *e*, leaf.
Fig. 172. *Laurus princeps*, Heer, leaf.
Fig. 172 *b*. Flower-buds.
Fig. 173. *Pimelea œningensis*. *a*, leaf, from Münsingen; *b*, flower, from Œningen, enlarged.

and France; and in most localities possessing Miocene plants they are frequently met with.

The *camphor-tree* of Switzerland had long-stalked elliptical leaves, narrowing into the petiole at the base and more or less acuminate at the apex; their long first lateral veins do not run parallel to the margins, and terminate at about two thirds of the length of the leaf. In their axils we sometimes observe a small wart. These leaves were shining, and have sometimes preserved their gloss even in the rock (as at Œningen). They issue from large oval buds, which are surrounded by oval scales. The small trimerous flowers are placed together in great numbers in loose panicles (fig. 171, *a*). They consist of six small sepals, obtusely rounded at the apex and traversed by thin longitudinal veins, placed round a median disk (fig. 171, *c*; enlarged, *b*). Remains of the stamens are sometimes preserved. The oval fruits (fig. 171, *d*) are surrounded at the base by a small plate, which originates from the calyx. In all these particulars the Swiss tree agrees with the living camphor-tree: the leaves are scarcely distinguishable; but in the existing species there are always small warts in the axils of the large lateral veins, which is not constantly the case in the fossil form; the flowers and fruits are also very similar, except that in the living species the sepals are slightly pointed at the apex, and the fruits are rather larger and nearly spherical, almost like a cherry. No doubt, therefore, the Tertiary camphor-tree, which occupies the left side in the Plate of "Lausanne in Miocene times," had the same appearance as its living representative. The latter is a native of Southern Japan and China, but it also thrives in Sicily and in Madeira. Prof. Heer has seen beautiful camphor-trees in the gardens of Funchal (Madeira). They attain the size of the European pear-trees, and have a shining foliage, of a lighter green than the laurel. The whitish flowers are small and inconspicuous; but as they are in great numbers and together, they serve to adorn this lovely tree. In Funchal, in 1851, the flowers first appeared in the middle of March, and at the end of that month the trees were covered with blossom; in Japan, according to Kämpfer, the time of flowering is in May and June.

The cinnamon-tree of Scheuchzer (fig. 170) was almost as generally distributed as the camphor-tree in the Swiss Miocene. It is distinguished from the preceding by its leaves not being acuminate, by their lateral veins being nearer and parallel to the margins, and also by its jointed peduncles and larger fruits. In all these respects it approaches the Japanese cinnamon-tree (*Cinnamomum pedunculatum*, Thunb.).

Cinnamomum lanceolatum, Ung., with longer and narrower leaves, occurs in the Lower Miocene, and is distributed over almost the whole Miocene land. It has not only been found in Central Europe, but also in the valley of the Cydnus in Asia Minor, and at Bovey Tracey in Devonshire. *C. Rossmässleri*, Heer, which had large elliptical leaves, with the lateral veins reaching to the apex as in the Indian cinnamon, inhabited the whole of Central Europe; and we even meet with a very similar form in Oregon in North America. *Cinnamomum spectabile*, Heer, which is confined to the Lower Miocene, had very large leaves (which are nearly 6 inches long and 2½ inches broad); it is particularly abundant at Eriz and Monod, where very fine leaves have been obtained.

Cinnamon-trees are all Asiatic forms; but the laurels in part resemble the southern European species, and, in part, types in the Canary Islands. The most abundant species is *Laurus princeps*, Heer (fig. 172), of which magnificent leaves, showing even the finest veins, have been found at Œningen (near Schrotzburg) and at Locle. These leaves attain a length of 6 inches and a breadth of 1½ inch, and in the fossil state show a peculiarly shining surface; so that they must have been perfectly smooth. Besides the leaves, the spherical flower-buds (fig. 172, *b*) and the oval fruit have been found. The species is very nearly allied to the Canarian laurel (*Laurus canariensis*, Sm.), which is the chief constituent of the evergreen forests of Teneriffe and Madeira. This "Louro," as the inhabitants of Madeira call it, is much larger than the European laurel; and its shining dark green foliage consists of longer leaves, traversed by a greater number of lateral veins. The whitish flowers open in March, forming elegant panicles issuing from the axils of the leaves; they afterwards become converted into oval berries. Prof. Heer remembers with much pleasure the charming laurel-groves of St. Anthony in Madeira, through which he made an excursion to the mountains in March 1851. A little brook, fringed with luxuriant ferns, rushed sparkling through the verdant ground, which was here and there variegated by the golden tufts of the broom and furze. Over all rose the beautiful shady roof of the laurel trees, with white bunches of flowers peeping from their dark green foliage; while the Canary birds resting on the branches filled the air with their joyous melodies. Such must have been the appearance of the Swiss princely laurel when it fringed the banks of the rivers and lakes of Switzerland. The *Laurus primigenia*, Ung., which occurs in the lower Swiss Miocene, is another nearly allied form, whilst the *Laurus Fürstenbergi*, A. Br., of Œningen, resembles the European species *L. nobilis*, Linn.

The genus *Persea* very closely approaches the true laurels in the structure of the leaves; and one of the species of the Swiss Miocene (*P. speciosa*, Heer) resembles the "Vinhatico" (*P. indica*, Linn.), a tree in the Canary Islands; whilst another (*P. Braunii*, Heer) is analogous to the American *P. carolinensis*, Cat. The Vinhatico grows higher than the Louro, and forms large trunks, the brown timber of which is known in commerce as Madeira mahogany, and is highly prized. In this, as in other Laurineæ, the main stem has divided very low down, so that several large trunks rise from a short thick stem, the dense foliage of their numerous branches forming a lofty dome of leaves. The Vinhatico grows in Madeira especially upon the banks of small streams and in deep gorges. In the middle of January Prof. Heer found it in the mountains of the Cural; and at the end of March, in the shady ravines of St. Pedro, he noticed it covered with half-ripe fruit.

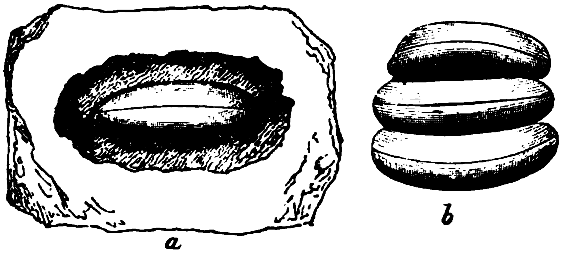
The camphor-trees, cinnamon-trees, laurels, and *Perseæ* no doubt formed large evergreen forest-trees; whilst three species of *Styrax* and a *Sassafras* were probably shrubs or small trees, like their American relatives. The Sassafras tree has on the same branch entire leaves and leaves divided into two or three lobes; and the same character is found in a fossil species from Sinigaglia and Menat; but as yet only entire leaves occur in the Swiss Œningian species *Sassafras Æsculapii*, Heer.

Of the Santalaceæ (Sandal-wood trees), which are allied to the laurels, only one species has been found in Switzerland; but this belongs to the well-marked Australian genus *Leptomeria* (*L. œningensis*, Heer). It was a shrub with small leaves adpressed to the branches. The little family of the Daphnoideæ is at present represented only by the Australian genus *Pimelea*. Of one species (*Pimelea œningensis*, Heer) Prof. Heer has leaves (fig. 173, *a*) and a blossom (fig. 173, *b*). The latter is surrounded at the base by a tuft of hairs, as in the existing species.

The *Proteaceæ* form a family still richer in species than that of the laurels; but its species are not so widely distributed, and do not occur in such great quantities. In the form of their leaves they resemble the Australian genera *Hakea*, *Dryandra*, *Banksia*, and *Grevillea*; and to these they have been referred. Of *Hakea salicina*, Heer, Prof. Heer has obtained from Œningen the leaves (fig. 184, *c*), the thick woody fruit (fig. 184, *a*), and the winged seeds (fig. 184, *b*), which show that the species is very nearly allied to *H. saligna*, R. Br., sp. A small species of *Dryandra* (*D. Schrankii*, Sternb., fig. 185), with long, narrow, rigid, pinnatifid leaves, is characteristic of the oldest Swiss Miocene (the marls of Ralligen, Weggis, and Schwarzachtobel), and presents a close resemblance to *Dryandra formosa*, R. Br., in the form of its leaves. Of *Grevillea* we find *G. Jaccardi*, Heer, at Locle, and the nearly allied *G. hæringiana* at Ralligen; both species have rigid, long, narrow leaves covered with a delicate network, just like those of the Australian species *Grevillea linearis* and *oleoides*, R. Br. The *Banksiæ* have the leaves narrowed towards the base, and traversed by a midrib which diminishes but little in thickness towards the truncated apex. Leaves of this kind are found belonging to six species in the Swiss marine Lower Miocene; they resemble those of *Banksia integrifolia*, *spinulosa*, and *attenuata*, R. Br. The fruit of one species has been found at the Rother Berg near Lucerne; at least it is probable that the fruit represented in fig. 173 B must be referred to a *Banksia*; it is lenticular, covered with fine rugosities, and furnished with a distinct median line. In size and form it resembles the fruit of *Banksia Cunninghami*.

The order Serpentarieæ or Aristolochiaceæ is represented only by three species of *Aristolochia*. They were probably climbing shrubs, which twined round the trees of the Miocene forest.

Fig. 173 B.



a. Banksia. Fruit, from the lower Miocene of the Rother Berg near Lucerne, found by Prof. Kaufmann.
b. Fruit of *Banksia Cunninghami* from Australia.

Of the apetalous or incomplete-flowered plants numerous representatives of the Chenopodiaceæ and Polygoneæ now exist, but only a few species have remained from Miocene times. Two species of knotgrass (*Polygonum cardiocarpum,* Heer, fig. 175, and *P. rotundatum,* Heer) have left their fruits surrounded by a broad wing-like border at Œningen, where also are found three *Salsolæ* (*S. Moquini, crenulata,* and *œningensis,* Heer, fig. 174), with elegant fruit-cups resembling five-petalled flowers. As the *Salsolæ* occur at present only on the sea-coast, and here and there in inland salt marshes, these species make it probable that there were still salt lakes in the neighbourhood of Œningen in the later Miocene times.

Monopetalous or gamopetalous plants, in which the corolla consists of united petals forming a single piece, are not frequent in Tertiary species. Of several great families, such as the Campanulaceæ, Labiatæ, Solaneæ, and Primulaceæ, no trace has yet been found in the Swiss Miocene; of others, namely the Borragineæ, Scrophularineæ, Gentianeæ, and Caprifoliaceæ, there are only faint and doubtful indications; a few small fruits and seeds and indistinct flowers have been preserved, which furnish vague evidence of the probable existence of these types of plants.

The Compositæ (or Synantheræ) have numerous Miocene species, of which, however, only the fruits are preserved. Prof.

Heer has described twenty-one species from Œningen, and has received several others. They were evidently brought together from a wide area; for only one or two specimens of most of the species have been found. Had they grown on the banks of the lake of Œningen, their fruits would probably have reached the mud of its bottom in greater numbers. They are long fruits longitudinally striated and furnished with a crown consisting of an erect thin tuft of rigid hairs (fig. 183), such as we see constantly upon fruits of thistles, dandelions, Scorzoneræ, &c. which have fallen into the water. In the plant the hairs are erect in the receptacle; in dry weather the hairs spread out, forming the pappus, which bears the fruit thus displaced from the receptacle through the air; if they fall into water the hairs fold together again, and resume their original position. The fruits found at Œningen cannot yet be referred with certainty to living genera; but we find among them forms which vividly remind us of the fruits of thistles, burdocks, and Scorzoneræ, and at any rate they leave no room to doubt that a considerable number of Compositæ flourished in the Œningian forest.

Vacciniea also were plentiful at Œningen as well as throughout the Swiss Miocene forests, some of them resembling in form the common bilberry (*Vaccinium myrtillus*) and also the bog-berry and cowberry (*V. uliginosum* and *V. vitis idæa*); but with these are associated some American types. These species, however, are founded only upon the leaves; and, considering the multiplicity of similar leaf-forms, they cannot be regarded as quite certain. On the other hand, besides well-preserved leaves (fig. 178, *b*), we have the fruit-cups (fig. 178, *a*), fruits, and seeds of an ebenaceous tree (*Diospyros brachysepala*, A. Br.) to identify that plant, which closely resembles the South-European *Diospyros lotus*, Linn., and probably, like it, formed low much-branched trees, with berries as large as a cherry, surrounded by the four-lobed fruit-cup. It was first discovered at Œningen, where the calyx and leaves were found; afterwards at the Hohe-Rhonen (where a calyx lay close to a leaf), near Rothenthurm, at the Albis, and near Delsberg and Eriz; it has also been found in Italy (Sinigaglia), Germany, and France, and consequently occupies a very wide area. A second species (*D. anceps*, Heer), allied to the American date-plum (*Diospyros virginiana*, Linn.), is much less frequent.

Asclepiadeæ (swallow-worts) are characterized by the peculiar amalgamation of the stamens with the pistil, and by their flat seeds furnished with a tuft of hairs and enclosed in a follicle. Prof. Heer has gathered, at Œningen, seeds of this kind, with the tuft of hairs (fig. 182), as well as fruits, together with leaves (fig. 181) very like those of an American swallow-wort (*Acerates longifolia*, Mich., sp.); these fruits and seeds probably belonged to a species which formed similar low bushes with narrow leaves and white flowers. *Apocynophyllum helveticum*, Heer, was most likely a bushy tree allied to the oleander; it is represented by a branch with fine opposite leaves found at Walpkringen, in the Canton of Berne.

Ashes (*Fraxinus*) have only left their winged fruit (fig. 179, *a*) and pinnated leaves (a leaflet, fig. 179, *b*), from which five species have been recognized in Switzerland, in which country only one ash exists as an indigenous tree; and the Miocene species differs from the modern tree. Their nearest allies are found in America and in the Caucasus.

Convolvulaceæ are represented by species of the remarkable Indian genus *Porana*, which consists of large climbing shrubs, bearing numerous flowers in loose panicles. The calyces are persistent, and surround the ripe capsule with their five dry leaves. This was the case also with the fossil species, one of which (*Porana œningensis*, A. Br., fig. 176) was tolerably plentiful at Œningen, and has left us its calyces and fruit. Probably, like its Indian relative (*P. volubilis*, Burm.), it climbed up to the leafy canopy of the trees; its dry fruit-cups would be easily carried away by the wind, and would thus reach the mud of the lake of Œningen.

Lianas twined round the trees of the Œningian forest. Fig. 180 represents the fine fruit of one of these (*Bignonia Damaris*, Heer), and fig. 180, *b*, the seed with its winged margin. The woody fruit is nearly 6 inches long, and half an inch broad. It has exactly the form of that of *Bignonia* (*Tecoma*) *radicans*, Linn., but belongs to the true *Bignoniæ*, as there is no stria or rib along the middle of the valves, such as in the *Tecoma* indicates the position of the dissepiment or partition attached

Fig. 177. Fig. 180. Fig. 183. Fig. 184.

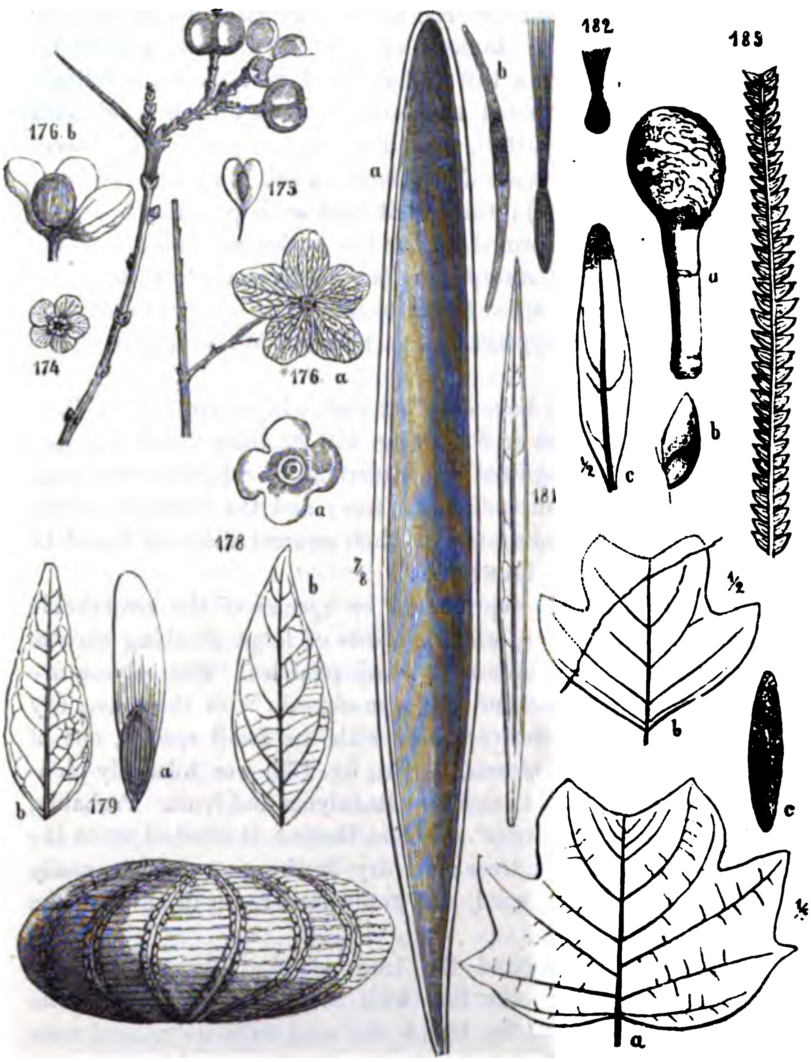


Fig. 187. Fig. 186.

Fig. 174. *Salsola œningensis*, Heer, fruit-bearing calyx.
Fig. 175. *Polygonum cardiocarpum*, Heer, fruit.

Fig. 176. *Porana œningensis*, A. Br., sp. *a*, fruit-calyx; *b*, fruit enveloped in the calyx.

Fig. 177. *Panax circularis*, Heer, from Œningen.

Fig. 178. *Diospyros brachysepala*, A. Br. *a*, fruit-calyx; *b*, small leaf.

Fig. 179. *Fraxinus prædicta*, Heer. *a*, fruit; *b*, leaf-pinnule.

Fig. 180. *Bignonia Damaris*, Heer, fruit ⅞ nat. size, from Œningen; *b*, seed.

Fig. 181. *Acerates veterana*, Heer, leaf.

Fig. 182. The same, seed with hair-tuft.

Fig. 183. *Cypselites costatus*, Heer.

Fig. 184. *Hakea salicina*, Heer. *a*, fruit; *b*, seed; *c*, leaf, ½ nat. size.

Fig. 185. *Dryandra Schrankii*, Br., from Weggis.

Fig. 186. *Liriodendron Procaccinii*, Ung. *a*, leaf from Iceland, ½ nat. size (restored); *b*, leaf from Eriz (restored), ½ nat. size; *c*, fruit from Iceland.

Fig. 187. *Apeibopsis Fischeri*, Heer, from Wynau.

there. The *Bignoniæ* are handsome climbing plants of the warm and torrid zones, the bell-shaped labiate flowers of which frequently show the most brilliant colours and contribute not a little to the adornment of the tropical forests.

Umbelliferæ, Ranunculaceæ, and Cruciferæ, belonging to the Polypetalous Dicotyledons, in which the corolla consists of several free petals, are represented in the Swiss Miocene by a few fruits. The fruits of *Ranunculus* and *Peucedanites* probably belonged to water and marsh plants; but those of *Clematis* were carried by the wind from the forest. The family Araliaceæ, which is most nearly allied to the Umbelliferæ, is represented by a small-leaved ivy (*Hedera Kargii*, A. Br.) and by the shrub *Panax* (*P. circularis*, Heer, fig. 177), of which a perfect branch with fruit has been obtained from Œningen. Of a species of vine (*Vitis teutonica*, A. Br.) nearly allied to the American fox-grape (*V. vulpina*, Linn.) only a few seeds and fruit-stalks have been found at Œningen; in Germany the leaves, berries, and seeds are known. The vine is therefore a primæval inhabitant of Europe, and no doubt festooned the Miocene oaks with its leafy garlands. Half a dozen species of dogwoods (*Corneæ*) have been obtained from the Swiss Miocene; the leaves are recognized by the lateral veins running to the apex. These trees probably formed tall copses like their living successors.

Magnoliaceæ are represented in the Swiss Miocene by a species of tulip-tree (*Liriodendron Procaccinii,* Ung.), first discovered at Sinigaglia, but which has since been found at Eriz in the Canton of Berne (fig. 186, *b*) and also in Iceland (fig. 186, *a*, *c*). The leaves are very like those of the American tulip-tree, the only known living species; they are truncated at the apex in the same peculiar manner as the leaves of the American tree; but the sides of the middle lobe are more rounded, and the fruits (fig. 186, *c*) are considerably smaller.

Water-lilies adorned the Miocene lakes in the vicinity of Lausanne; and their magnificent leaves have been collected at Paudèze. A peculiar species of *Nymphæa* (*N. Charpentieri,* Heer), resembling the Swiss white water-lily, occurs in the same locality, as well as a *Nelumbium* (*N. Buchii,* Ett.), which had shield-shaped leaves that probably rose above the water as in the existing species, whilst in the true water-lilies the leaves float upon the water. At Paudèze we have not only these leaves, but also the rhizomes of *Nymphæa* and *Nelumbium.* In *Nymphæa* the rhizomes are thick and set all round with large leaf-scars; whilst in *Nelumbium* they are quite smooth, and only furnished here and there with tufts of roots, from which the leaves ascend. According to the analogy of the living species, the Miocene water-lily probably had white, and the *Nelumbium* pale red flowers.

Myrtles, now found exclusively in warm and hot regions, are especially recognizable by the venation of the leaves, a vein from the base of the leaf running along each margin to the apex, and separating a narrow border. Prof. Heer has referred seven of the Swiss Miocene species to this family. Three of them belong to the true myrtles; and of these *Myrtus helvetica,* Heer, reminds us vividly of the species which inhabits the Mediterranean countries; whilst a *Eugenia* resembles the tropical rose-apple (*Eugenia Jambos*), and a fine *Eucalyptus* (*E. oceanica,* Ung.) approaches the Australian gum-trees.

Tiliaceæ (lime trees) are represented by forms which are now quite foreign to Switzerland. They belong to two genera. Of one of these (*Grewia*) the reniform or cordate crenated leaves are among the commonest fossils at the Hohe-Rhonen; so that an actual forest of *Grewia crenata* must have existed there. The fruits of the other genus are peculiarly interesting. They look like little gourds, but are traversed by from five to sixteen furrows, representing internal placentæ, to which the small seeds are attached in two rows. They closely resemble the fruit of the *Apeibæ* of tropical America, which, like the fossils, are not unlike sea-urchins; and this is especially the case with a greatly depressed broad form (*Apeibopsis Fischeri*, Heer, fig. 187), which agrees precisely in size with the fruit of *Apeiba Tibourbou*, Aubl. They differ, however, in the position of the seeds, and belong to a peculiar extinct genus. These fruits have been found in the Grey Miocene of Lausanne, and in the nodular sandstones in the vicinity of Morgenthal (Berne); leaves also occur at Monod and Eriz which resemble those of the *Apeibæ* in form and venation.

Acerineæ (maples) held a very important position in the Swiss Miocene flora; their species were more numerous than they are at present in any country of the world. Switzerland and Germany together now possess only 5 species; while in Prof. Heer's 'Tertiary Flora' the Professor has described 20 Swiss species, 16 of which lived in the forests of Œningen. Some of these species are still doubtful; but of 10 species not only the leaves were ascertained, but also the unmistakable fruits, and of some even the flowers, buds, and branches; so that they were absolutely determined. The principal species of the existing flora (the sycamore and the Norway maple, *Acer pseudoplatanus* and *Acer platanoides*) have no representatives in the Miocene, and the species belonging to the Miocene are generally most like North-American forms. The most important species is the three-lobed maple (*Acer trilobatum*, Sternb., fig. 190), which is one of the principal forest-trees of the Tertiary land. It not only extends through all the stages of the Swiss Miocene, and is one of the commonest trees at Œningen, but it has also been discovered in Germany, France, and Italy. Its area of distribution stretches over 18 degrees of longitude (from Menat in the Auvergne to Tokay) and 7 degrees of latitude (from Sinigaglia to Schossnitz near Breslau). The long-stalked trifid leaves are of considerable size (Prof. Heer has specimens 6 inches long and broad), and their lobes are irregularly toothed at the edges. The flowers were arranged in pendent umbels; and they have been so well preserved at Œningen that the sepals and petals and the ovary and stamens can be distinguished*. In its leaves, flowers, and fruit this tree so nearly approaches the red maple (*Acer rubrum*, Linn.) of America that it may be regarded as the ancestor of the red maple, from which it differs only in its thick petioles, in the absence or slight prominence of the basal lobes of the leaves, and its larger fruit attached to stronger peduncles. The red maple is spread in marshy low grounds from Canada to the southern United States, and forms moderately large trees with pendent red fruit-stalks. The nearest relative of this species in the American flora is the woolly-fruited maple (*Acer eriocarpum*, Ehrb.), a large handsome tree, represented in the Swiss Miocene flora by *A. eriocarpoides*, Heer, a species which, however, is much less frequently met with. This is the case also with the vine-leaved maple (*Acer vitifolium*, A. Br.), which is most nearly allied to another American species (*A. spicatum*, Lam.) lately found growing in the Amoor district. One of the most elegant species (*A. Ruminianum*, Heer, fig. 191), distinguished by its long-lobed and sharply toothed leaves and by its small fruit, most closely resembles a Japanese species (*A. polymorphum*, Sieb.), which must be very abundant, as its leaves are constantly represented in Japanese pictures. Leaves and fruits of *A. Ruminianum* have been obtained at Monod and near Wangen. Besides these exotic forms, some European types occur, representing *Acer campestre*, *A. opalus*, Ait., and *A. monspessulanum*, Linn., species which are met with here and there in Switzerland, but belong properly to the Mediterranean zone. Two or three peculiar forms are found in the Swiss Miocene which have no living analogues, such as the large-winged maple (*A. otopteryx*, Gœpp., fig. 192), the fruit of which attains a length of 4 inches. It has lately been found at Œningen and Elgg, but was previously known in Carinthia and Silesia, and even in Iceland, where this maple was the most abundant deciduous tree in Miocene times. Prof. Heer has received leaves and fruit from Brjamsloek, Gualthame, Hredavatn, and Tindarfell. Fig. 193 represents the smallest of these leaves; but some occur 3 inches wide. They are cordate at the base, and have not very prominent lobes; and their edges are irregularly toothed.

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* Fig. 190, *d* (p. 360), represents an umbel. On the lower flower we can recognize four delicate petals inside the calyx, the fifth having probably fallen; the two other flowers show us the ovary, which consists of two carpellary leaves. In a second umbel (fig. 190, *b*) the sepals and petals have fallen, and the ovary is further advanced on its development into the fruit. In fig. 190, *c*, we have an umbel of male flowers with the stamens, the oval anthers of which are very well preserved. This tree, therefore, like the red maple, bore male flowers besides the pistilliferous ones. Fig. 190, *e*, shows a fruit-umbel. The two carpellary leaves have here become developed into two long wings, which are widened in the middle, obtusely rounded at the apex, and pretty strongly inclined forward. Besides leafy branches we have obtained naked ones, evidently of autumn or winter, and garnished with opposite oval buds. Fig. 190, *f*, shows the extremity of such a branch.

Sapindaceæ are allied to the maples, although of quite different appearance; and one of their species (*Sapindus falcifolius*, A. Br.) was abundant in Switzerland, appearing in all stages of the Swiss Miocene. It closely resembles the savonnier of Surinam (*Sapindus surinamensis*, Poir.), and possessed, like it, handsome pinnate leaves with numerous ovate-lanceolate pinnæ and globular fruit.

Frangulaceæ furnished the principal part of the shrubs which formed the underwood in the forests, and the copses in the marshes and along the banks of the rivers, in the Swiss Miocene country. We find an abundance of species belonging to the three families Celastrineæ, Rhamneæ, and Ilicineæ. The Celastrineæ were generally evergreen shrubs with rigid coriaceous leaves, resembling species now found at the Cape of Good Hope, in Australia, and in South America. The commonest species is *Celastrus Bruckmanni*, A. Br., a shrub with small oval leaves, small 5-petaled flowers, and a thin-lobed capsule. The Rhamneæ are more abundant, and belong to five genera, whilst we at present only possess one, the genus *Rhamnus*, of which two species grow in the low country. From the Swiss Miocene we have fourteen species of *Rhamnus*. Of these, we may especially notice *Rhamnus Gaudini*, Heer, which furnished the most abundant leaf at Monod (Canton of Vaud). This species had large, oval, dentate leaves, traversed by eight to twelve curved lateral veins. The species of *Zizyphus* and *Paliurus* were thorny shrubs, of which the spiny branches, the leaves traversed by thin longitudinal veins, and the small flowers have been discovered. *Zizyphus Ungeri*, Heer (fig. 195), is confined to the lowest Swiss Miocene (Val d'Illiers, Ralligen, and Horw), and represents the

Fig. 192. Fig. 190.

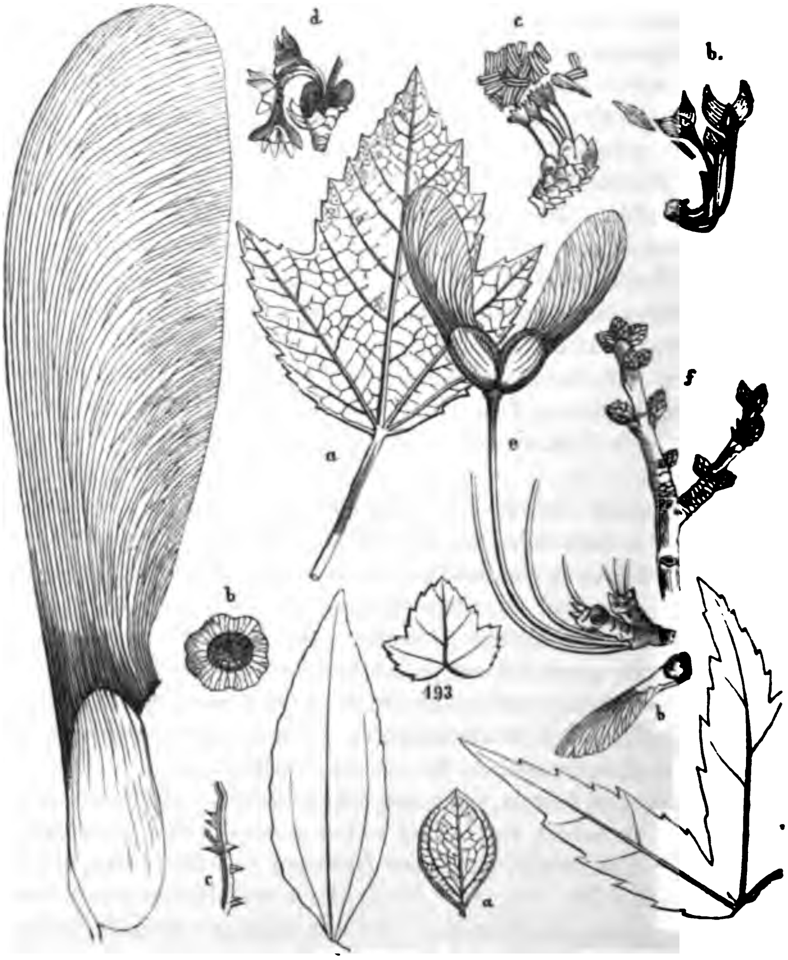


Fig. 194. Fig. 195. Fig. 194. Fig. 191.

Fig. 190. *Acer trilobatum*, Sternb., sp., from Œningen. *a*, leaf; *b*, young fruit; *c*, male flowers; *d*, female flowers; *e*, ripe fruit; *f*, naked branch with buds.

Fig. 191. *Acer Ruminianum*, Heer, leaf; *b*, fruit, from Wangen.

Fig. 192. *Acer otopteryx*, Gœpp., fruit from Œningen.

Fig. 193. Young leaf from the Surturbrands of Iceland.

Fig. 194. *Paliurus Thurmanni*, Heer, from Locle. *a*, leaf; *b*, fruit; *c*, twig with spines.

Fig. 195. *Zizyphus Ungeri*, Heer, leaf from Morgins in the Val d'Illiers, ½ nat. size.

Japanese *Zizyphus sinensis*, Lam.; whilst *Z. tiliæfolius*, Ung., extends from the lower into the upper Miocene, and is widely distributed beyond the limits of Switzerland: it was one of the most abundant species. At the Hohe-Rhonen Prof. Heer obtained its leaves, spines, and small four-petaled flowers on the same slab. It is most nearly related to the Asiatic jujube-tree (*Zizyphus jujuba*, Lam.). The *Paliuri*, on the contrary, are constructed on the type of the Christ's thorn (*Paliurus aculeatus*, Lam.), which is common in Southern Europe. Like this species, the *P. Thurmanni*, Heer, from Locle, had spiny branches (fig. 194, *c*), elliptical leaves traversed by lateral veins running to the apex (fig. 194, *a*), and a dry fruit surrounded by a winglike border (fig. 194, *b*). *Berchemia multinervis*, A. Br., sp., was no doubt a large climbing shrub. In its oval leaves, traversed by numerous parallel lateral veins and very close fine veinlets, it agrees exactly with *B. volubilis*, Linn., a shrub which, in Carolina and Florida, often embraces the trees so closely as to obstruct their growth and even to destroy them, so that it has not without reason received the name of the "trees' executioner." The Tertiary species probably had a similar mode of growth. It was widely distributed.

A species of holly is still to be found wild in the Swiss woods. The Miocene country of Switzerland had nine species, one of which (*Ilex Studeri*, Lah.) resembles the common holly in its rigid, leathery, sharply spinous leaves, whilst the others all remind us of forms which are now met with in the swamps of Carolina, Georgia, and Florida. The leathery fruits and spinous leaves of the *Ilex berberidifolia*, Heer, are particularly well preserved at Œningen and Locle; the nearest ally of this species is the *Ilex cassine*, Ait., of Carolina.

Terebinthineæ, in Miocene times, were not only more abundant than at present in Switzerland, but they presented a much greater variety of forms. This is the case especially with the

Juglandeæ (walnuts), of which Prof. Heer has described sixteen species. Of some of these species he only knows the leaves, and of others only the fruit; and perhaps four species will have to be combined; but there still remain twelve species, whilst Europe now possesses not a single indigenous walnut-tree; and even North America, where the family attains its maximum, can only show ten species. Consequently the Juglandeæ occupied a more important position in the Miocene than in the existing flora, and some of the species were very abundant, and spread over the Miocene country. The sharp-leaved walnut (*Juglans acuminata*, A. Br.) appears in all the stages of the Swiss Miocene, and has also been found in Germany and Italy. Its area of distribution embraces seven degrees of latitude and about ten degrees of longitude. It was most nearly allied to the common walnut (*J. regia*, Linn.), the native country of which is Persia. The leaves were of large size and pinnate; the pinnæ had entire margins, and were placed in pairs, with a single foliole at the end of the leaf. The male flowers were united into rather long catkins. The fruits were rather smaller than those of the Swiss walnut, but they had, like it, a wrinkled shell. Of this species, however, only badly preserved and much compressed specimens have hitherto been found; but fine nuts belonging to two allied species (*Juglans Gaudini*, Heer, and *J. Blancheti*, Heer) have been discovered in the Canton of Vaud. The distribution of *Juglans bilinica*, Ung., was the same as that of the sharp-leaved walnut. In the form of its dentate folioles it resembled the black American walnut (*J. nigra*), which is often seen in Swiss plantations, and which is distinguished by its spherical deeply wrinkled nuts. The *Caryæ*, on the contrary, have smooth nuts; *Carya elænoides*, Ung., and *C. Heerii*, Ett., are of most frequent occurrence in the Swiss Miocene. In its long, narrow, serrated leaflets the *Carya Heerii* resembles the marsh hickory (*Carya aquatica*, Mich.), which inhabits the swamps of Carolina and Georgia. *Pterocarya denticulata*, O. Web., sp., was probably a dense bushy tree; in the structure of its leaves it is very like the Caucasian species (*P. caucasica*, Kth.). A fine pinnate leaf has been obtained of it from the Hohe-Rhonen.

Anacardiaceæ are well represented by the genus *Rhus* (sumach) in the Swiss Tertiary flora. The most abundant species is *Rhus Pyrrhæ*, Ung., probably a shrub with compound leaves, representing the American aromatic sumach (*R. aromatica*, Ait.); next to this comes Merian's sumach (*R. Meriani*, Heer), which, like the American vinegar-tree (*R. typhina*, Linn.) often grown in Swiss gardens, possessed pinnate leaves. This species and *R. Brunneri*, Heer, which also had pinnate leaves, are confined to the Swiss lower Miocene.

The species of *Xanthoxylon* were spiny shrubs with compound pinnate leaves; and those of *Ailanthus* were probably trees of considerable size. Of one species the winged fruits have been found at Hohe-Rhonen.

The Calophyta are very scantily represented in the Swiss Miocene. The herbaceous Rosaceæ occupy a very prominent place in the existing flora; but these plants are wanting in the Swiss Miocene flora, and even the shrubby and arborescent forms are by no means numerous. Of the Pomaceæ we have only the genus *Cratægus*, three species of which belong to the group of the common whitethorn. One of them (*C. Buchii*, Heer), lately discovered at Œningen, has exactly the leaves of the whitethorn. The family Amygdaleæ is better represented by the two genera *Prunus* and *Amygdalus*. One species (*Prunus acuminata*, A. Br.) closely resembles an American cherry-tree (*P. chicasa*, Mx.); a second species (*P. Hanhardti*, Heer), discovered at Berlingen, is like the common plum; and a species of almond (*Amygdalus pereger*, Ung.) has the leaves and fruit-stones of the common almond. Thus the primitive forms of the cherry-, plum-, and almond-trees existed in the flora of the Swiss Miocene.

Leguminosæ in Tertiary times, as at present, formed an order including a very great number of species. In the flora of the Swiss Miocene this order takes the first place, with 131 species. Of many of these, indeed, we know only the leaves; but of 21 we have also the characteristic pods.

Swiss Miocene Leguminosæ belong to two families, the Papilionaceæ and the Mimoseæ—the latter now wanting in Europe, but represented by numerous species in the tropical and subtropical zones. The Mimoseæ are generally trees or shrubs remarkable for their fine and multipinnate leaves; they are among the most elegant of plants. The two principal genera are the *Acaciæ* and the *Mimosæ*, both of which formerly lived in Switzerland. Of the latter we have only a fruit from one of the erratics of St. Gall, the determination of which cannot be regarded as quite certain; but of the Acacias we have numerous leaves and well-preserved pods. One species (*Acacia parchlugiana*, Ung.) possessed pretty bipinnate leaves and long pods, and in appearance probably resembled the living *Acacia lophanta*, W., and *A. dealbata*, Link. This is the most abundant plant in the erratics of St. Gall, where the fruits are to be found side by side with the leaves. It also occurs in the neighbourhood of Lausanne, and is represented by the shrub with fine feathery foliage in the foreground of the plate of "Lausanne in the Miocene epoch." As this tree can be traced as far as Central Italy (Sinigaglia) in one direction, into Auvergne (Menat) in another, and eastwards to Tokay in Hungary, it must have had a very wide area of distribution. A second widespread species is *Acacia Sotzkiana*, Ung., which had larger leaflets and smaller pods; whilst a third (*A. microphylla*, Ung.) has only been found in a few places, and ten more species appear to belong exclusively to the Swiss Miocene flora.

Papilionaceæ of the Swiss Tertiary formation may be arranged in five groups—the Loteæ, Phaseoleæ, Dalbergieæ, Sophoreæ, and Cæsalpinieæ. The last four groups are foreign to the present flora of Switzerland; but the Loteæ possess numerous Swiss species, and are found throughout the temperate zone. The Swiss Miocene flora, however, includes only fifteen species of this group, and the Papilionaceæ belong chiefly to the exotic groups. Moreover, of the fifteen species of Loteæ only six belong to genera (namely, *Cytisus*, *Medicago*, and *Colutea*) which form part of the existing Swiss flora, and there are six genera not represented in it. In general the Papilionaceæ contribute much to impress a southern character on the Swiss Tertiary flora. In the temperate zone their species are almost exclusively herbaceous; but in the warmer zones many shrubs and trees belong to that family; and in the Miocene we find an abundance of Papilionaceous woody plants. At the same time it must be borne in mind that most of the species are scarce, probably because they grew rather on dry hills than in marshes or along the banks of rivers.

Of the trefoils we have only the fruit of a medick (*Medicago protogæa*, Heer) and of a *Trigonella* (*T. Seyfriedi*). We know the leaves and a fruit of a bladder-senna (*Colutea*), and the small, palmate, trifoliate leaves of a laburnum (*Cytisus*). The most abundant tree of this group is the *Robinia Regeli*, Heer, which most nearly resembles the common red robinia (the false acacia) of our gardens. The beautiful pinnate leaves of this tree have been preserved at Œningen, and, together with the large many-seeded pods, are found in the Molasse of Lausanne and the erratics of St. Gall.

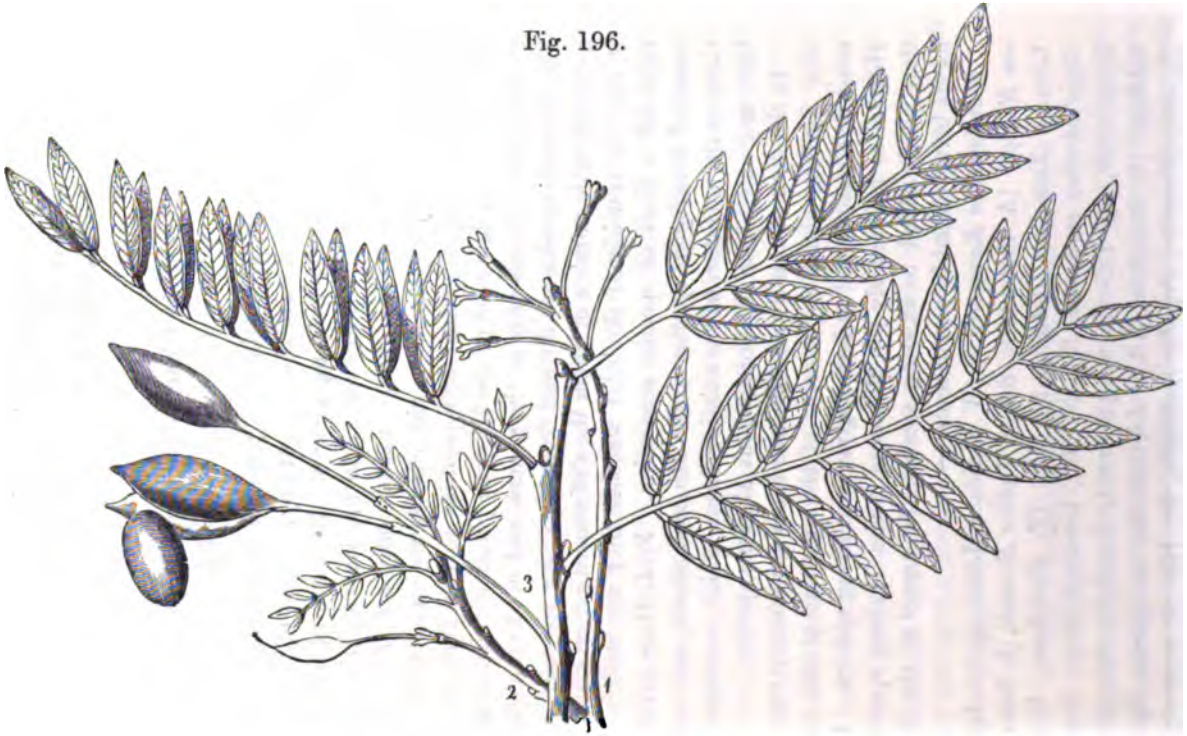
In the group of the Dalbergieæ, the genus *Dalbergia* includes the greatest number of species; they were probably shrubs and small trees with leathery pinnate leaves, such as now grow in Northern India. The Sophoræ have a widely distributed species, *Sophora europæa*, Ung., which resembles the Indian *Sophora tomentosa*, Linn.

The Cæsalpinieæ constitute the most important group of the Papilionaceæ, and have thirty-eight species in the Swiss Miocene. The two principal genera are *Cæsalpinia* and *Cassia*. The *Cæsalpiniæ* were probably gnarled trees with bipinnate leaves. A fine leaf of *C. Escheri*, Heer, with the rachis armed with fine spines, was obtained at Œningen; this tree, and the nearly allied *C. Falconeri*, Heer, and *C. micromera*, Heer, most resembled the Brazilian *C. mucronata*, W., and probably belonged to a group of Brazilian trees possessing gnarled trunks, bipinnate spiny leaves, and golden-yellow flowers. Two other species (*C. lepida*, Heer, and *Laharpii*, Heer), on the contrary, vividly remind us of the sappan bush (*Cæsalpinia sappan*, Linn.), which is a native of India, but now grows wild in great abundance in Madeira, where it hangs down over rocks and walls and clothes them with its elegant dark green foliage, from which peep forth, in spring, charming bunches of golden-yellow flowers. In Switzerland we find the *Cæsalpiniæ* especially in the upper Molasse, whilst the *Cassiæ* are distributed through all the stages. Several species (namely *Cassia Berenices*, *hyperborea*, *phaseolites*, *lignitum*, and *ambigua*, Ung.) are among the most abundant Papilionaceæ of the Swiss Miocene flora. They were, no doubt, handsome shrubs with shining green pinnate leaves and bunches of yellow flowers, like their living American allies. *Cassia coccinea*, Heer, is an elegant species, of which a leafy branch has been obtained at Œningen. The delicate leaflets are folded together in the sleeping state like those of the fine-leaved *Cassiæ* (such as *C. microphylla*, W.).

The *Gleditschiæ* announce their presence by large spines, leaves, and fruit. These trees are now foreign to Europe; but the genus *Ceratonia* is represented in the south of Europe by the carob, locust, or St.-John's-bread tree (*C. siliqua*), which closely resembles a species found at Œningen.

The *Podogonium* constitutes a peculiar extinct genus. It approaches the tamarinds in the form and venation of the leaves and in the structure of the seed, but differs from them entirely in its fruits. The principal characters of this remarkable tree may be seen in fig. 196. The long pinnate leaves, terminating in a pair of leaflets, are supported on thin branches. One or two of the first lateral veins of the lower side of each leaflet are very long and run to the apex of the leaflet, whilst those of the other side are not longer than the rest. The little flowers are placed on naked branches (fig. 196, 1); the calyx, which is tubular below, is divided at the summit into four lobes; but whether it bore a corolla cannot be ascertained. The germen, which protrudes from the tube of the calyx, is pedunculate within the flower, and contains a single ovum. It becomes converted into a pod, which is supported on a long stalk, and when ripe splits down to the base into two valves (fig. 196, 3). The large round seed then falls out of the fruit. At Œningen there have been found a number of opened fruits with the seed sometimes lying beside them, sometimes only half or one third free from the valves. The tamarind has non-dehiscent many-seeded fruit. Prof. Heer, in his 'Tertiary Flora,' has described six species of *Podogonium* from Œningen; and of these *P. Knorrii* and *P. Lyellianum*, Heer, are of most frequent occurrence. They are characteristic of the Œningian stage, from which strata they have been collected near Schrotzburg, at the Albis, and the

Fig. 196.



Podogonium Knorii, A. Br., sp. 1. Flowering branch. 2. Young branch with a young fruit. 3. Leafy branch with ripe fruit. This was found in Œningen. Prof. Heer has only restored the leaves from other specimens.

Irchel near Baden, and at Locle. From Germany also Prof. Heer has seen the remains of these trees from the tufas of Hohe-Rhonen, Günzberg and Randeck in Wirtemberg, from Elbogen in Bohemia, and even from Tokay in Hungary; they were consequently widely distributed.

V. *Comparison of the Plants of the Swiss Miocene with the present Flora of Switzerland.*

In the Miocene epoch the flora presents the same general appearance with the flora of the present day. Most of the species can be ranged under existing genera. Of those genera which have been so perfectly preserved as to furnish us with satisfactory characters for their determination, only six (*Physagenia, Calamopsis, Najadopsis, Laharpia, Apeibopsis,* and *Podogonium*) can be indicated as extinct and peculiar to the Tertiary flora. The agreement, however, of the Miocene plants with those of the existing flora extends only to the genera, and not to the species. The Miocene species are distinct from the living species; but in a considerable number of them the differences are so small that it may be considered doubtful whether they are sufficient to establish a limit of specific separation. Prof. Heer gives the name of *homologous species* to the Miocene plants, and regards them as the ancestors of the existing forms, which, consequently, have originated from the homologous Miocene species.

In the flora of the Swiss Miocene there are seventy-two species, forming about 9 per cent. of the vascular plants, which must be characterized as homologous with living species. Prof. Heer cites particularly the following Swiss Tertiary species as thus nearly allied to existing species, the names of the living forms being placed in parentheses:—

Woodwardia Rœssneriana (W. radicans, Linn., sp.); *Aspidium Escheri* (A. thelypteris, Sw.); *Isoëtes Braunii* (I. lacustris, Linn.); *Taxodium dubium,* fig. 156 (T. distichum, Rich.); *Glyptostrobus europæus,* fig. 155 (Gl. heterophyllus); *Sequoia Langsdorfii,* fig. 159 (S. sempervirens, Lamb.); *Sparganium valdense* (S. ramosum, Ait.); *Liquidambar europæum,* fig. 165 (L. styracifluum); *Populus mutabilis,* fig. 166 (P. euphratica);

P. balsamoides (P. balsamifera, Linn.); *P. latior* (P. monilifera, Ait.); *Salix varians* (S. fragilis, Linn.); *Ulmus Braunii*, fig. 168 (U. ciliata, Ehr.); *Planera Ungeri*, fig. 167 (P. Richardi, Mich.); *Platanus aceroides* (P. occidentalis, Linn.); *Laurus princeps*, fig. 172 (L. canariensis, Sm.); *Cinnamomum polymorphum*, fig. 171 (C. camphora, Linn.); *C. Scheuchzeri*, fig. 170 (C. pedunculatum, Thb.); *Hakea salicina*, fig. 184 (H. saligna, R. Br.); *Diospyros brachysepala*, fig. 178 (D. Lotus, Linn.); *Acerates veterana*, fig. 181 (A. longifolia, Mich.); *Fraxinus prædicta*, fig. 179 (F. oxyphylla, M. Br.); *Liriodendron Procaccinii*, fig. 186 (L. tulipifera, Linn.); *Acer trilobatum*, fig. 190 (A. rubrum, Linn.); *A. eriocarpoides* (A. eriocarpum, Ehrh.); *A. decipiens* (A. monspessulanum, Linn.); *Paliurus Thurmanni*, fig. 194 (P. aculeatus, Lam.); *Zizyphus Ungeri*, fig. 195 (Z. sinensis, Lam.); *Berchemia multinervis* (B. volubilis); *Robinia Regeli* (R. hispida, Linn.); *Gleditschia Wesseli* (G. triacantha, Linn.).

Besides these species, which are so nearly allied to species now living that it is probable they have a genetic connexion with them, there are many others which are less nearly related to living forms, but which yet closely resemble them; and these are termed by Prof. Heer *analogous species*. Others, again, differ completely from all living forms, and represent peculiar extinct types of plants, although they may be incorporated with existing genera, such, for instance, as the great horsetail (*Equisetum procerum*), the feather-palms, the large-fruited maple (fig. 192), and the nelumbo (*Nelumbium Buchi*). Several alders, birches, and hornbeams, as well as some oaks, fig-trees, Cæsalpiniæ, Dalbergiæ, and Acacias, differ widely from all existing species, and represent forms of plants making their first appearance during the Tertiary epoch, and not being any more met with after that period.

VI. *Characters of the Swiss Miocene Flora.*

The homologous and analogous species show us that the most similar plants are not to be found in the present Swiss flora, but generally in distant lands; so that, although on the whole the Miocene flora is very like that now existing, a complete change has taken place in the natural productions of Central Europe since the Tertiary times, and the localities where Miocene plants are now found are remote from their former habitation.

If we bring together, according to their native countries, the living homologues of the Swiss Miocene species, we find that 33 species live in America, 16 in Europe, 12 in Asia, 2 on the Atlantic islands, and 3 in Australia; to these we must add 4 species common to Europe and the Atlantic islands, 4 common to Europe and Asia, and 2 which live both in Europe and America.

Extending this comparison to both homologous and analogous species, we obtain the following numbers. Of the species most nearly resembling the Swiss Miocene species, 83 live in the northern United States, and 103 in the southern United States, 40 in tropical America, 6 in Chili, 58 in Central Europe, 79 in the Mediterranean zone, 23 in the temperate, 45 in the warm, and 40 in the torrid zone of Asia, 25 in the Atlantic islands, 26 in Africa, and 21 in Australia.

These numbers show that at the Miocene period Switzerland was inhabited by types of plants which are now scattered over all parts of the world, but that most of them correspond to American species; Europe only stands in the second rank, Asia in the third, Africa in the fourth, and Australia in the fifth. Most of the analogous species of Europe are found in the Mediterranean countries, in America in the southern United States (Louisiana, Florida, Georgia, and Carolina), and also in California, in the Caucasian region of Asia, in Japan, in Asia Minor, and in Madeira and the Canary Islands. Swiss Miocene species are also represented in the torrid zone of Asia, in the Sunda Islands, and in tropical America.

When the mass of vegetation is considered which was the special characteristic of Switzerland in Miocene times, greatly increased prominence is given to the Japanese types by the abundance of camphor-trees and *Glyptostrobi*; to the Atlantic element by the laurels; to the American types by the numerous evergreen oaks, maples, poplars, planes, liquidambars, *Robiniæ*, *Sequoiæ*, *Taxodia*, and ternate-leaved pines; and to the Asia-Minor types by the *Planeræ* and a species of poplar (*Populus* *mutabilis*). The greatest number and the most important of the types of the Swiss Miocene flora belong, therefore, to a belt lying between the isothermal lines of 59° and 77° Fahr. (15° to 25° Cent.); and in this zone America is now the region mostly correspondent to the natural character of the Swiss Miocene land.

There is found in the flora of the Swiss Miocene a peculiar mixture and association of the species of plants, by which forms now widely separated are brought together and extinct types are discovered, thus conferring a singular interest on the Miocene vegetable remains of Switzerland.

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Page 230, line 14, *for* leafy trees are not found *read* only one species of leafy trees is found.

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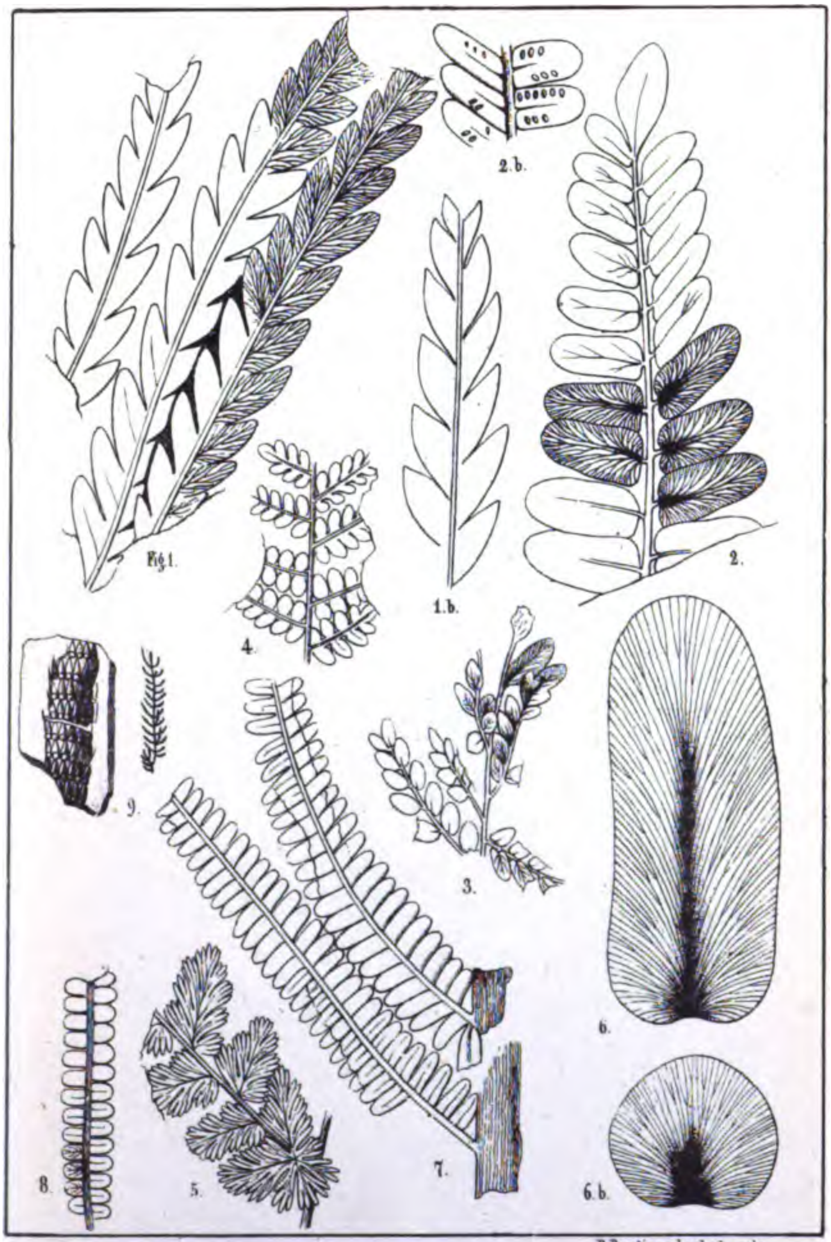

P. Brugier ad nat. et sculp.

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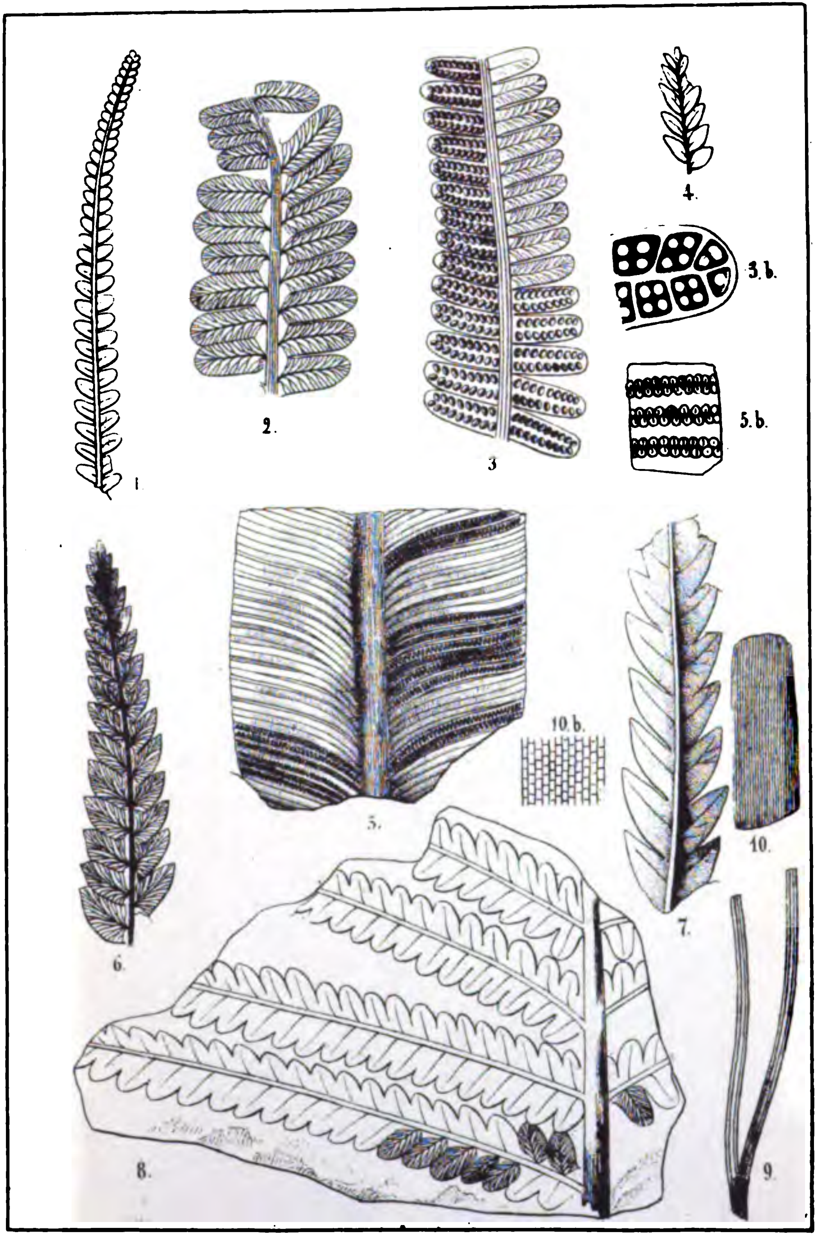
KEUPER PLANTS.

Taf. II.



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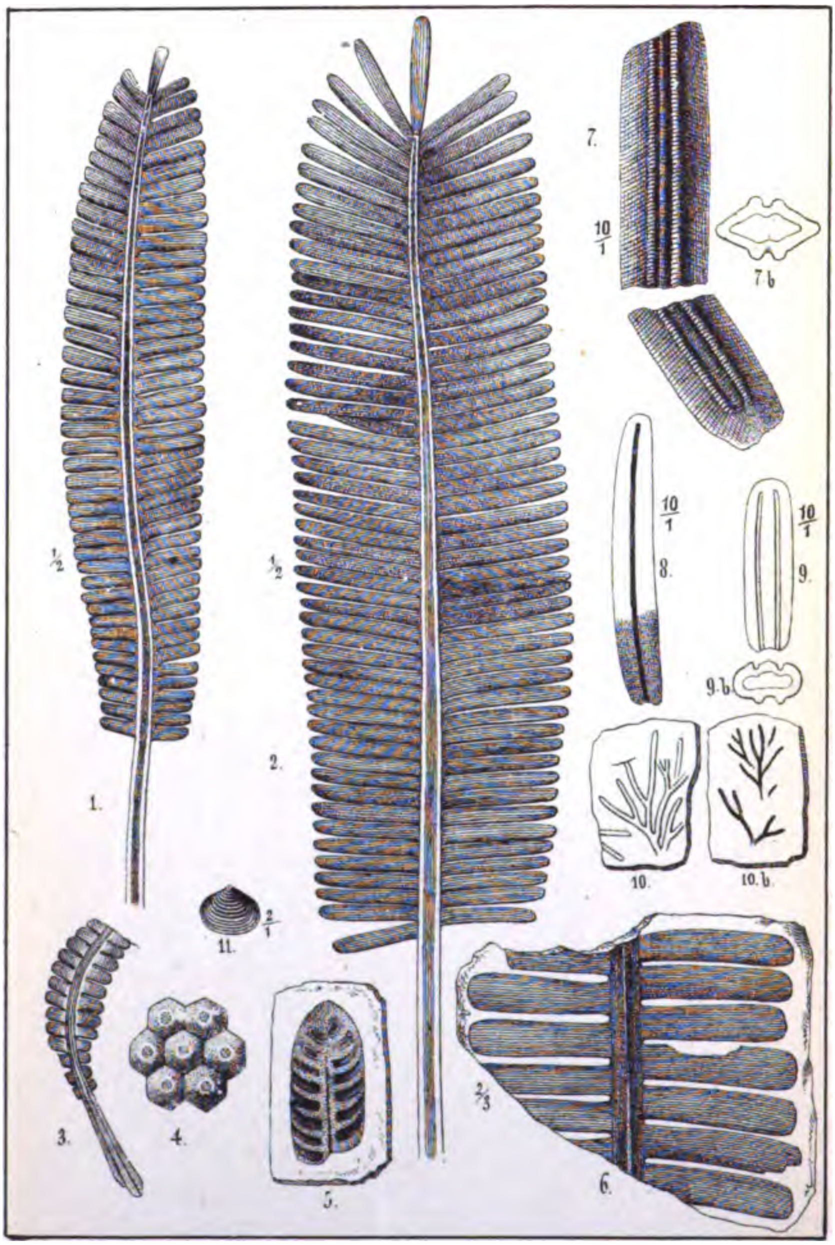
KEUPER PLANTS.

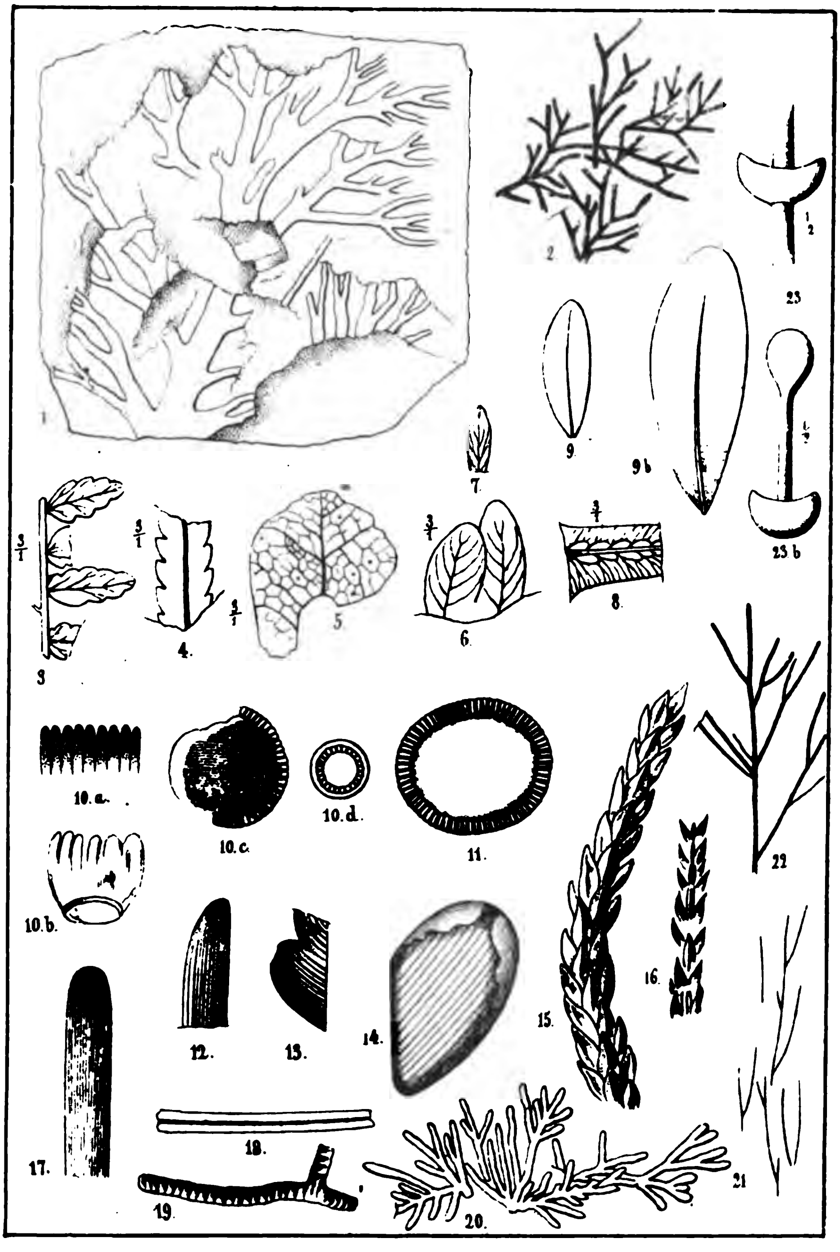
Taf. III.



1. Pterophyllum brevipenne. 2. Pterophyllum Jaegeri. 3. Pterophyllum Meriani. 4.5.6. Pterophyllum longifolium. 7. Bactryllium striolatum. 8. Bactryllium Schmidii. 9. Bactryllium canaliculatum. 10. Chondrites prodromus. 11. Estheria minuta.

LIASSIC PLANTS.

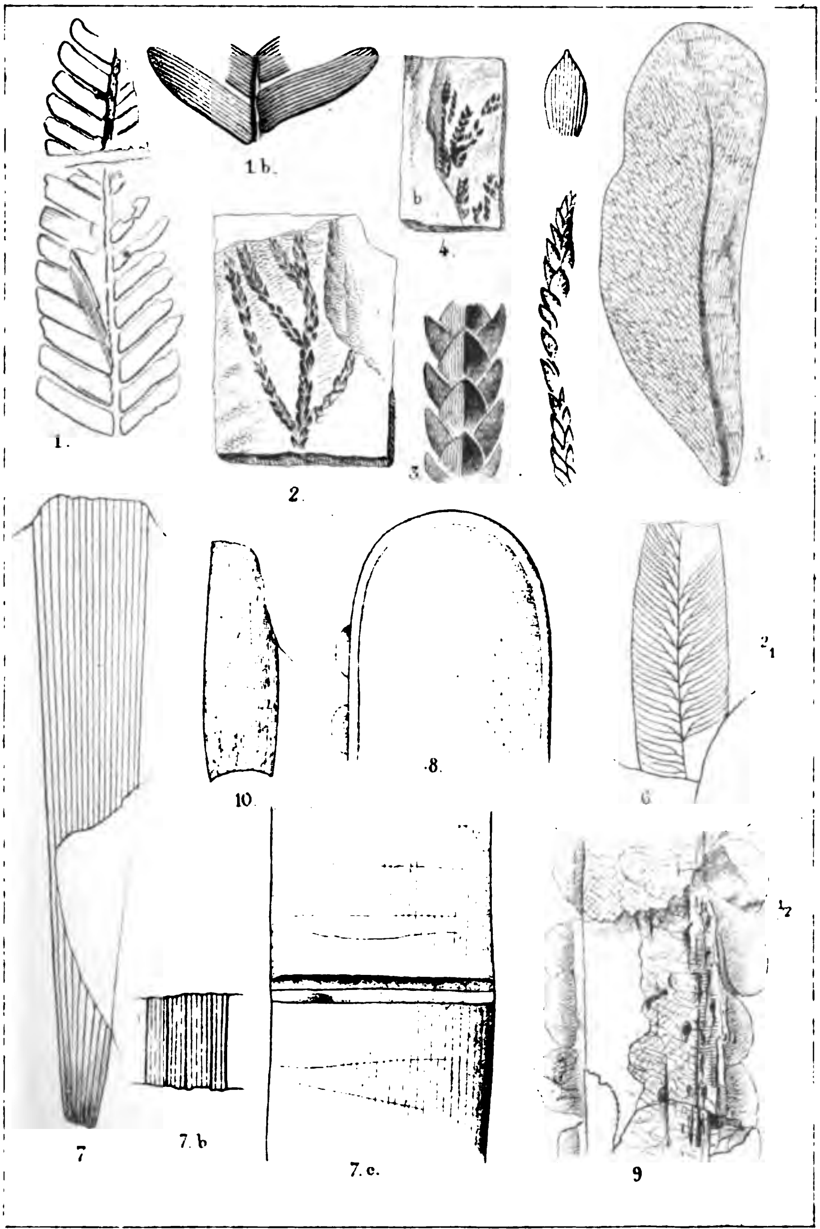
Pl. IV.



1. Zonarites Schambelinus. 2. Chondrites liasinus. 3. Sphenopteris Renggeri. 4. Pecopteris debilis. 5. Camptopteris Nilssoni. 6 Pecopteris arcinervis. 7. Pecopteris deperdita. 8 Phlebopteris polypodioides. 9. Sagenopteris gracilis. 10. 11. Equisetum liasinum. 12 Pterophyllum Hartigianum? 13. 14. Nilssonia Kirchneriana? 15 Auracarites peregrinus. 16. Thuites fallax. 17. Zosterites tenue-striatus. 18. Cyperites protogaeus. 19. Münsteria antiqua. 20. Chondrites bollensis. 21. Chondrites Padellae. 22. Chondrites filiformis. 23. Fucoides Moeschii.

LIASSIC PLANTS.

Pl V.

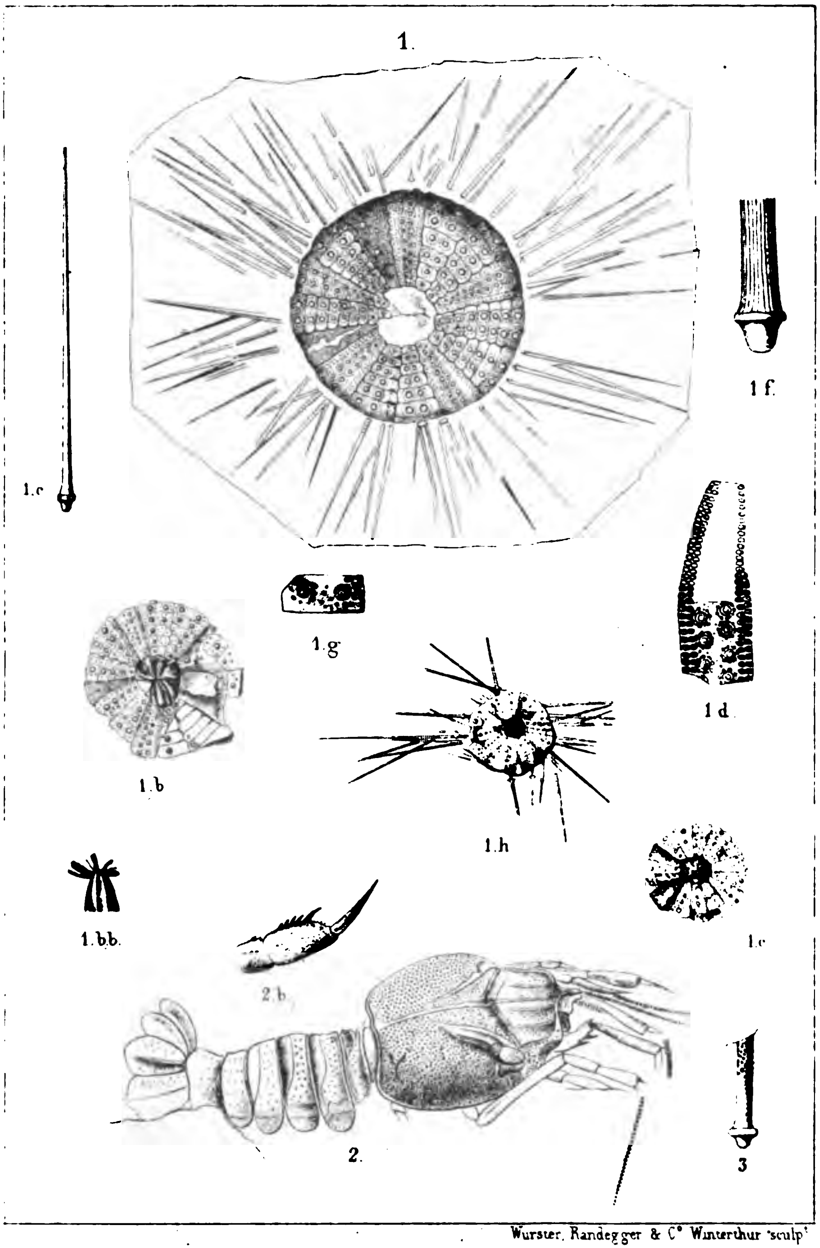


Wurster Randegger & C. Winterthur [illegible]

1 Zamites gracilis. 2. 3 Thuites fallax. 4. Widdringtonites liasicus. 5. Sagenopteris Charpentieri. 6. Pecopteris osmundoides. 7 Bambusium liasinum 8. 9 Cycadites procerus. 10. Pterophyllum acutifolium ?

LIASSIC ANIMALS.

Pl. VI.

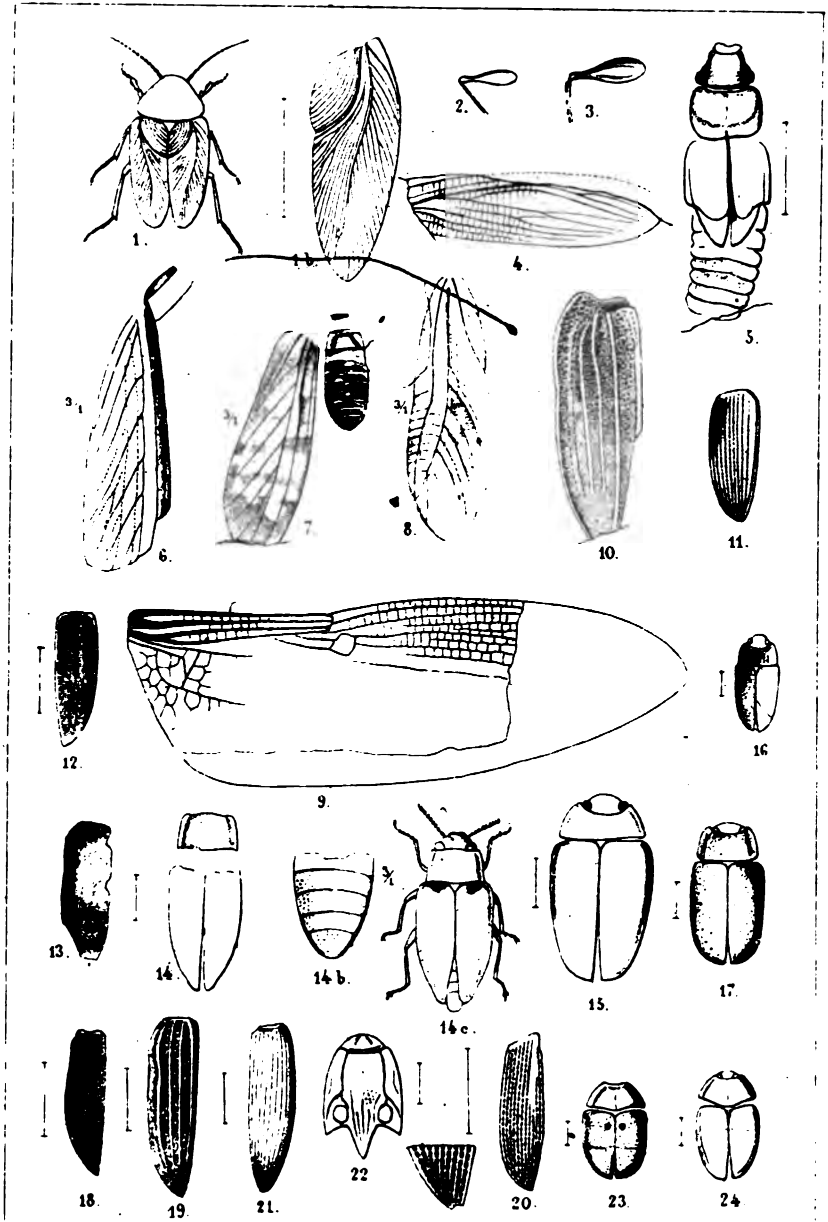


Wurster, Randegger & Cº Winterthur sculpt.

1. Diademopsis Heerii Mer. 2. Glyphea Heerii Opp. 3 Cidaris psilonoti Qu

LIASSIC JNSECTS.

PL VII.

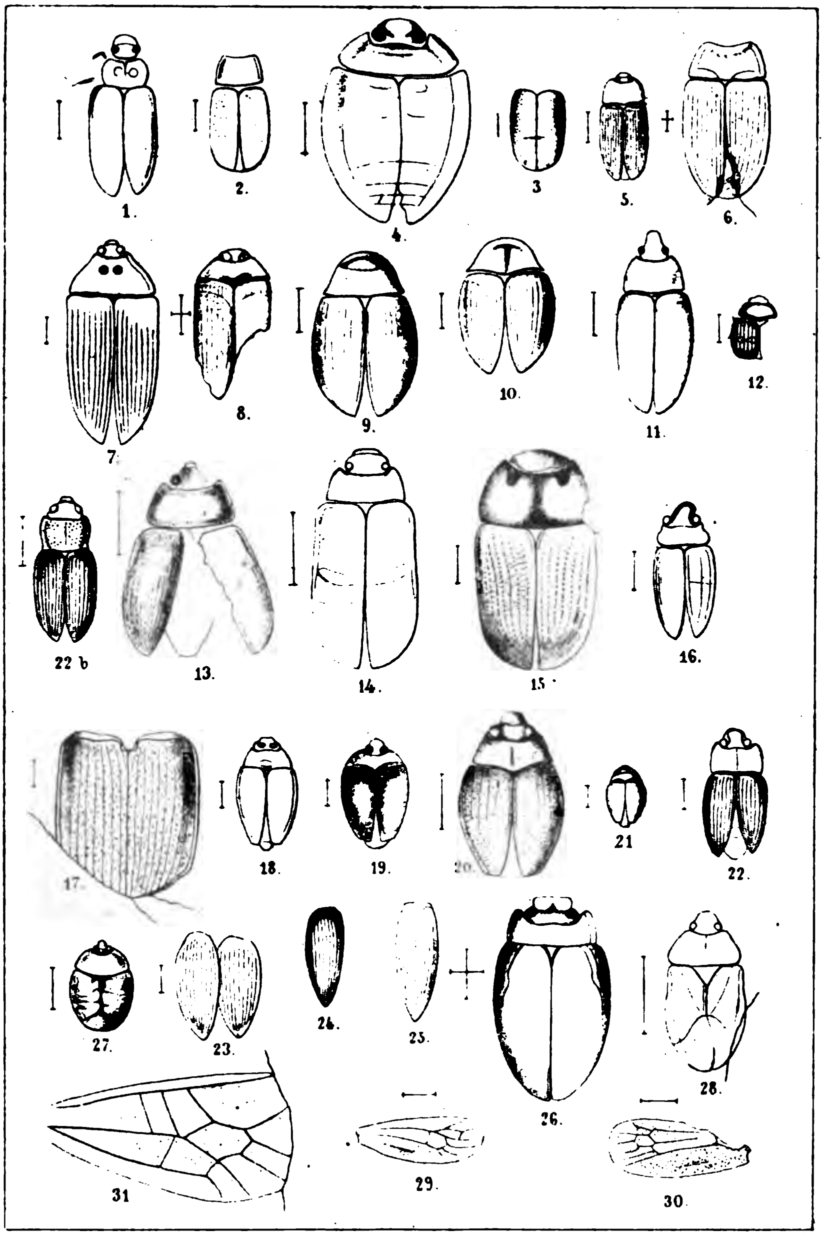


Wurster Randegger & Comp Winterthur lith.

1. Blattina formosa. 2. 3. Gomphocerites Bucklandi 4 Acridites deperditus. 5. Baseopsis forficulina. 6 Calotermes plagiatus. 7. C maculatus. 8. Clathrotermes signatus. 9. Aeschna Hageni 10. Euchroma liasina. 11. Buprestites Lyellii. 12 Glaphyroptera Gehreti. 13. Gl insignis. 14 Gl. gracilis. 15. Gl. brevicollis. 16. Micranthaxia rediviva. 17. M. bella. 18. Melanophila sculptilis. 19. M costata. 20. Bothynophora elegans 21. Elaterites vetustus. 22 Megacentrus tristis 23. Strongylites stygius. 24 St. morio.

LIASSIC JNSECTS.

PL. VIII.

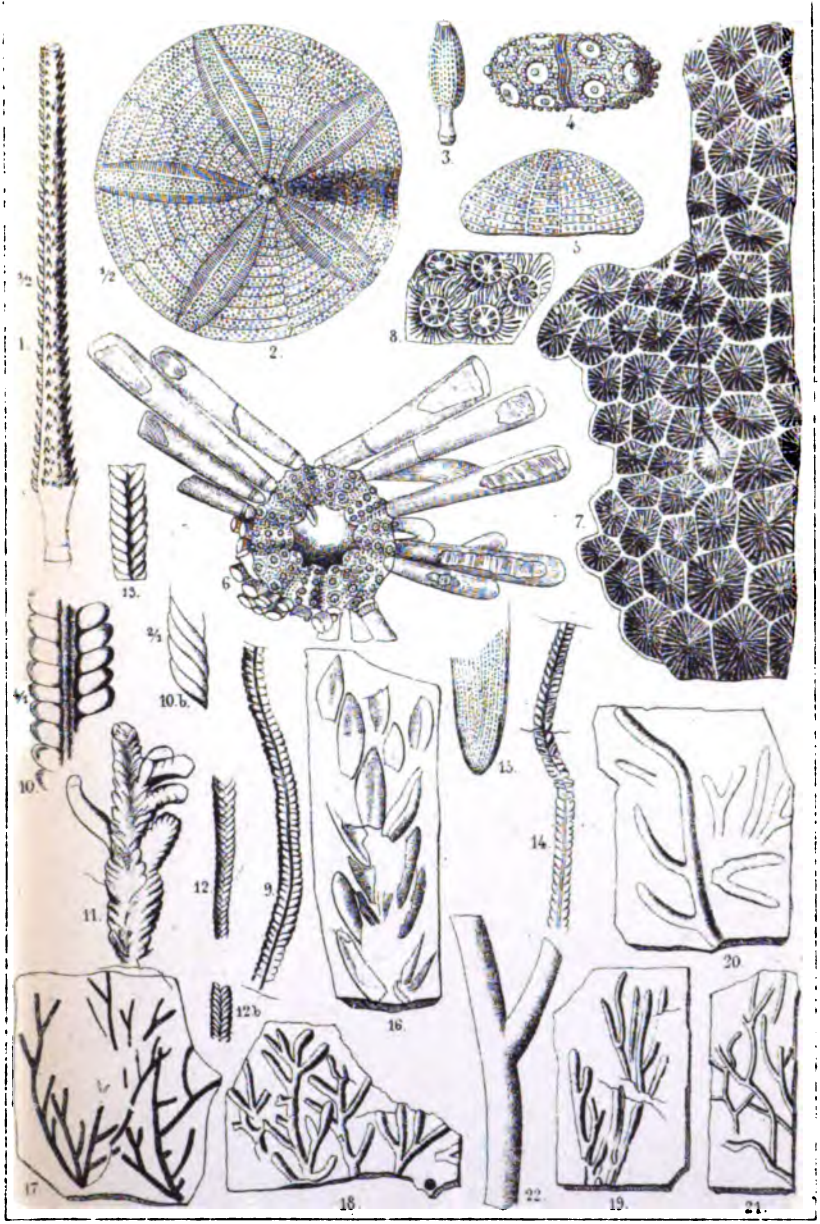


Wurster, Randegger & Cº Winterthur, sculpt.

1. Latridiites Schaumii 2. 3. Nitidulites argoviensis. 4. Cycloderma deplanatum 5. Bellingera laticollis 6. B. ovalis 7. Prototoma striata. 8. Trixagites floralis. 9. Byrrhidium arcuatum. 10. B. morio 11 Cistelites insignis. 12. Petrorophus truncatus. 13. Chrysomelites prodromus. 14. Eumolpites liberatus. 15 Aphodiites protogaeus. 16. Sitonites melanarius. 17 Thurmannia punctulata. 18 Gyrinus atavus. 19 Gyrinites troglodytes. 20 G. antiquus. 21. G. minimus. 22. Carabites bellus. 22. b. C harpalinus. 23. Hydrobiites veteranus. 24. Hydrophilites stygius. 25. H. Acherontis 26. Wollastonites ovalis. 27. Cyclocoris pinguis. 28. Protocoris insignis. 29. Cercopidium minutum. 30. C. morio. 31. Palaeomyrmex prodromus.

JURA.

Pl. IX.

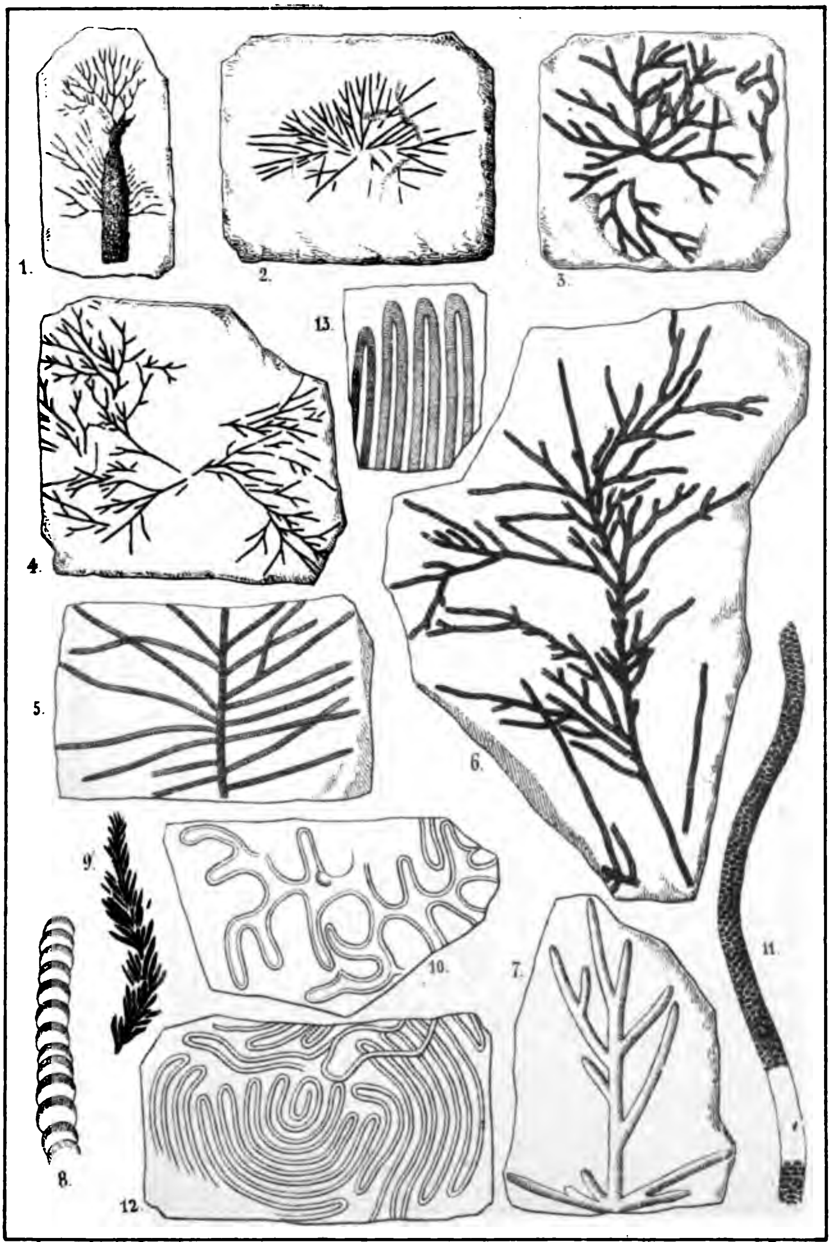


Wurster Randegger & C.ie Winterthur sculp.

1. Rhabdocidaris nobilis. 2 Clypeus sinuatus. 3. 4 Cidaris coronata 5 Holectypus depressus. 6 Hemicidaris crenularis. 7. Isastraea helianthoides. 8. Stylina castellum. 9. 10. Gyrochorte vermicularis. 11. G. ramosa. 12. G. comosa. 15. 16. Araucarites Meriani. 17. Chondrites aemulus. 18. 19. Nullipora hechingensis. 20. N. argoviensis. 21. N. angustus. 22. Cylindrites Langii.

FUCOIDS OF THE FLYSCH.

Pl. X.



Lith. Anst. v. F. Schulthess, Zürich.

gez. v. P. Brugier.

1. 2. Chondrites intricatus. 3. Ch. Targionii expansus. 4. Ch. intricatus Fischeri. 5. Ch. patulus. 6. Ch. Targionii arbuscula F. C. 7. Ch. inclinatus. 8. Münsteria annulata. 9. Caulerpites filiformis. 10. Palæodictyon singulare. 11. Halymenites lumbricoides. 12. 13. Helminthoida labyrinthica.